United States
Department
of Agriculture

Forest Service

Intermountain
Research Station

General Technical
Report INT-228

The Grand Fir/Blue Huckleberry Habitat Type in Central Idaho: Succession and Management

Robert Steele
Kathleen Geier-Hayes

THE AUTHORS

ROBERT STEELE is a research forester on the Douglas-fir and Ponderosa Pine Ecosystems Research Work Unit, Boise, ID. Since joining the Intermountain Station in 1972, he has worked full time on development of forest habitat type classification, and classification and management of successional forest communities. He earned a B.S. degree in forest management and an M.S. degree in forest ecology at the University of Idaho.

KATHLEEN GEIER-HAYES is a forester on the Douglas-fir and Ponderosa Pine Ecosystems Research Work Unit. She has worked part time on the classification and management of successional forest communities since the beginning of this project in 1979 and joined the Intermountain Station on a full-time basis in 1986. She earned a B.S. degree in biology at Boise State University and an M.S. degree in forest science at the University of Idaho.

ACKNOWLEDGMENTS

Financial support for this study was provided by the Intermountain Region of the Forest Service, U.S. Department of Agriculture, through a memorandum of understanding with the Intermountain Research Station.

Staff of the Boise and Payette National Forests assisted at various times with logistical support and helpful information during field sampling. Phil Straub (Boise National Forest) and Glenn Jacobsen (Payette National Forest) provided continued support and helpful advice on the development of this study and the preliminary draft of this report. Dave Marben and Bill Terrill (Boise National Forest) also provided useful comments and suggestions during a preliminary review. Pete Stickney (Intermountain Research Station) generously shared his data and insight on similar forest succession studies.

RESEARCH SUMMARY

A system for classifying vegetational succession in the grand fir/blue huckleberry habitat type is presented. The system is based on reconnaissance sampling of 92 stands: 14 old-growth sites, 20 old-growth sites paired with disturbed sites, and 38 unpaired disturbed sites. A total of 21 potential tree layer types, 28 shrub layer types, and 36 herbaceous layer types are categorized by a hierarchical taxonomic classification. Diagnostic keys based on indicator species are provided for field identification of the layer types.

The management implications of various seral conditions are discussed. Implications include: occurrence of pocket gophers and success of tree plantations by site preparation treatments, initial growth rates of tree seedlings and yield capability of mature trees, microsite needs of natural tree seedlings, big-game and livestock forage preferences of shrub and herb layer types, and responses of major shrub and herb layer species to various disturbances. Species composition data for various types of tree, shrub, and herb layers are displayed in tables.

December 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

CONTENTS

TABLES

FIGURES

FIGURES (Con.)

The Grand Fir/Blue Huckleberry Habitat Type in Central Idaho: Succession and Management

Robert Steele
Kathleen Geier-Hayes

INTRODUCTION

Over much of the West, development of habitat type classification based on potential natural vegetation (Pfister 1984) has fostered a growing awareness of vegetation and its variability. Those who manage natural resources now recognize the need to foresee impacts of their activities on the present vegetation and to understand possible changes that may result. But in order to understand all facets of vegetal change, one's perspective must encompass the often bewildering integration of cause and effect, and random, cyclic, and temporal relationships that are manifest in succession dynamics. Logically, the first step is to reduce this complexity to a manageable number of recognizable units in the form of a classification.

Habitat type classifications focus on the environmental (site) differences affecting vegetation. They provide a logical framework for studying succession and occasionally infer successional relationships but offer no classification of seral communities. As one approach to meeting this need, we present herein a classification of seral vegetation designed for general field use. In so doing, we have attempted to exploit the fact that natural classifications, in contrast to technical ones designed for a specific use, have broader application and often provide greater prediction capability. The widely accepted habitat type system of classification is an outstanding example of a natural classification and as its originators, R. and J. Daubenmire (1968), have pointed out "...that system may be considered the closest to a natural one that allows the most predictions about a unit from a mere knowledge of its position in the system." We developed the following classification with these criteria in mind so that the relative position of a classified unit in the system can help predict the successional direction of that unit. By doing this, we found that some types of seral vegetation are strongly related to a specific disturbance; other types develop mainly through uninterrupted succession. These cause and effect relationships are presented in various ways in the sections dealing with classification as well as those dealing with management implications.

Throughout this text the reader must remember that vegetation is influenced by time and environment. Environment, as it affects vegetation, can be delineated by habitat types or potential climax communities (Daubenmire 1952) that are relatively stable barring disturbance. In a similar manner, time, as it relates to succession, can be segmented by community types or seral stages that can be obliterated, slightly altered, or even advanced through various disturbances. Habitat type classifications have proven useful in much of the West (Layser 1974) and by focusing on climax potential enable investigators to hold time constant while grouping plant communities according to their environment. Conversely, environment can be held relatively constant by using habitat types while focusing on vegetal dynamics over time.

This report explores the changes in vegetation and related resource values occurring over time in one forest environment, the *Abies grandis/Vaccinium globulare* habitat type (ABGR/VAGL h.t.) (Steele and others 1981). The classification approach used here recognizes the individual nature of specific sites in terms of existing and potential species composition. It also recognizes that land managers need site-specific guidelines for intensive management purposes. In this regard, management implications for many species can be derived from each species' reaction to a particular disturbance and its successional strategy. This report can be applied to specific sites by understanding the successional characteristics presented for each major species and then synthesizing that knowledge for the existing and potential species on a particular site. Sometimes, the preliminary nature and meager data base herein require tentative use as a management guide. Throughout this report, users should focus on the relative nature of data presented rather than absolute values. This report is the result of 4 years of field sampling, preliminary drafts, and field testing. Suggested revisions and user feedback were analyzed and often adopted. These inputs have improved results of this report, but because this report was developed through a series of approximations, it should always be open to further refinement.

This report applies one concept for classifying seral vegetation (Steele 1984). It recognizes the somewhat independent nature of succession between the tree, shrub, and herbaceous layers (often due to layer-specific disturbances such as selective tree harvesting or grazing) and treats these three successions separately. It recognizes the high potential diversity of early and mid-seral vegetation and the relative forage values to livestock and big game. It also indicates some interrelationships of site treatment, planted tree survival, competing vegetation, and pocket gopher populations. Most important, it provides a common framework for communication among various disciplines.

Objectives

The objectives of this report are:

1. To develop a classification of seral community types in the ABGR/VAGL h.t. based on indicator species and vegetal structure.

2. To identify successional relationships of community types and relate these communities to the management treatments that gave rise to them.

3. To present species composition and canopy coverage information for each community type and the relative value of shrub and herbaceous community types as forage for big game and livestock.

4. To describe natural and artificial establishment and early growth characteristics of tree regeneration in relation to site treatment, microsite conditions, and competing vegetation.

5. To determine the number of years required for each tree species to reach breast height (4.5 feet, 1.4 m) in the ABGR/VAGL h.t.

6. To provide a basis for developing preliminary management implications by seral community type.

METHODS

Field Methods

Sampling methods followed those used previously in the central Idaho habitat type study (Steele and others 1981), with some modification. Thus sampling was done "subjectively but without preconceived bias" as described by Mueller-Dombois and Ellenberg (1974). Reconnaissance surveys were taken through areas known to have quantities of the grand fir/blue huckleberry habitat type as well as some disturbance from wildfire, timber harvest, and site preparation for tree planting. Potential sample sites were noted as to habitat type, kind and uniformity of disturbance, dominant vegetation, and approximate year of disturbance. Sample plots were selected to represent the range of site conditions and diversity of seral vegetation characteristic of the habitat type. In some cases, paired samples were selected from homogeneous sites that were partly in old-growth timber and partly in early seral condition. To the extent that time allowed, a large proportion of the available sites were sampled, with elimination of obviously duplicated situations in close proximity as well as sites where the treatment appeared to have been nonuniform.

Most seral stands that were sampled resulted from timber harvest. A few resulted from wildfire. The kinds of treatments sampled included: clearcut with no site preparation; clearcut and broadcast burned; clearcut, burned, and scarified; clearcut and scarified; and wildfire. Various grazing and browsing intensities by cattle, sheep, or big game also occurred on many of these sites. Circular sample plots nearly 1/10 acre (375 m^2) in size were located in representative portions of stands to reflect a certain treatment. Estimates of treatment age were obtained from all stands by various means, which included management records, evidence of tree growth release from increment cores, cross-sections of fire scars and machine scars on trees, and tree plantation signs. Plot centers were marked with a labeled wooden stake and referenced to roadside features to enable revisitation during the study. In all plots, the following observations were recorded.

Amounts of all vascular plant species were estimated by seven canopy-coverage classes (trace = 0-1 percent coverage, 1 = 1-5 percent, 2 = 5-25 percent, 3 = 25-50 percent, 4 = 50-75 percent, 5 = 75-95 percent, 6 = 95-100 percent). Species present in the stand but not in the plot were recorded as a "+". For maximum efficiency, these coverages were estimated within the entire 1/10-acre (375-m^2) macroplot (Pfister and Arno 1980) instead of using a series of small quadrats (Daubenmire 1959). The coverage class values were used directly in synthesis tables and ordinations. The canopy coverage for each tree species was subdivided into four diameter classes—less than 4 inches (10.2 cm), 4-12 inches (10.2-30.5 cm), 12-18 inches (30.5-45.7 cm), and over 18 inches (45.7 cm). Percentage of the surface covered with exposed mineral soil and rock was also estimated.

Trees more than 4.5 feet (1.4 cm) tall were tallied by 2-inch (5.1-cm) d.b.h. classes according to species. Trees between 4.5 (1.4 m) and 0.5 feet (0.15 m) tall were simply tallied by species. From 1979 to 1982, microsite conditions of trees older than 3 years and less than 4.5 feet (1.4 m) in height were recorded by species in a 538-ft^2 (50-m^2) circular plot. In 1983 the 538-ft^2 (50-m^2) plot was modified into five 108-ft^2 (10-m^2) circular plots so as to improve sampling accuracy. One 108-ft^2 (10-m^2) plot was placed at the macroplot center, two others were placed 18 feet (5.5 m) from each side of macroplot center along the contour, and the other two were placed 18 feet (5.5 m) from macroplot center perpendicular to the contour. All microsite conditions associated with tree seedlings were recorded in the 538-ft^2 (50-m^2) plot area. Observations were recorded regarding the association of each tree seedling with soil surface characteristics such as bare soil, litter, moss mats, or rotten wood and influential vegetation, or debris such as shrubs, grasses and forbs, rocks, or logs. Pocket gopher mounds made during the current year were also counted in the 538-ft^2 (50-m^2) area. If no mounds were found in the 538-ft^2 (50-m^2) area, the 4,037-ft^2 (375-m^2) macroplot was searched and the mounds were tallied accordingly.

Unidentified plants on each plot were collected and preserved for later identification or verification. A few plants in flower were also collected for voucher specimens. Many specimens collected during a previous study of the same area (Steele and others 1981) served as vouchers. Plant taxonomy follows Hitchcock and Cronquist (1973).

Observations were made on fire history, windthrow, snow damage to tree seedlings, insect and disease occurrence, grazing, use by wildlife, and distance from plot center to nearest mature conifer seed sources. Methods of logging, slash disposal, site preparation, and planting and seeding attempts were described and dated by various means: increment cores, fire scars, logging scars, land management records, or plantation signs.

When available, free-growing trees of each species present were measured for height and age in order to estimate site potential by species. Suitable site trees for each species were not always available, especially in the denser stands or in early seral stages. Free-growing shrubs were also measured for height when existing growth from sprouts or seedlings had been clearly initiated by a site treatment of known age.

Thicknesses of litter, fermentation, and humus layers were measured at three locations in the plot. Soil parent material, which is relatively uniform in the study area, was also identified when exposed by natural outcrops, road cuts, erosion, or logging disturbance.

From 1979 to 1981, plots in the grand fir/blue huckleberry habitat type were sampled when encountered during reconnaissance of other habitat types in central Idaho and a preliminary report was prepared (Steele and Geier-Hayes 1982). The summers of 1982 and 1983 were devoted to preliminary succession studies of Douglas-fir/ninebark and Douglas-fir/pinegrass habitat types (Steele and Geier-Hayes 1983, 1984). In the summer of 1984, sampling efforts again focused on grand fir/blue huckleberry and the adjacent grand fir/mountain maple habitat type (Steele and Geier-Hayes 1985), both of which occur mainly on the Boise and Payette National Forests. All of these sample data for grand fir/blue huckleberry plus data for mature stands from the habitat type classification study (Steele and others 1981) were used in this report.

Office Methods

After each field season, collected specimens of plants were identified. Occasionally some were sent to the University of Idaho herbarium for verification. Unknown vegetative material was compared with identified flowering specimens. All positive identifications were entered on the field forms and numerically coded for computer processing.

Prior to this overall study, little effort had been devoted to formulating an ecologic classification system for seral forest communities. Consequently, considerable time was spent during the first 2 years developing concepts and methods of classification technique. The resulting approach to classifying seral vegetation is presented in a separate paper (Steele 1984) that follows a cone model concept of succession (Huschle and Hironaka 1980). These concepts were applied to the ABGR/VAGL field data after the 1981 and 1984 field seasons in the following manner:

1. All available data for the ABGR/VAGL h.t., including habitat type classification data (Steele and others 1981), were examined to determine which species in the tree, shrub, and herb layers have potential to become well represented (>5 percent canopy coverage). From these data, three lists of indicator species were assembled, one for each vegetation layer, and the species were ranked subjectively according to their relative vulnerability to successional replacement (see figs. 2, 9, 19) as suggested by field observations, sample data, and available literature. (Relative vulnerability reflects the integrated effects of succession such as species longevity, shade tolerance, allelopathic and disease resistance, and reproduction strategy. Relative shade tolerance is often the apparent factor that determines vulnerability, but, as Minore (1979) suggests, other factors may be involved. Bazzaz (1979) addresses numerous physiological factors that affect relative vulnerability.) Species having similar successional roles and vulnerability, such as *Ribes viscosissimum* and *Ribes lacustre*, were lumped in order to simplify the lists.

2. From each list of indicator species a separate tentative classification diagram (see figs. 3, 10, 20) was generated. The most vulnerable indicator species forms the base of each diagram, with progressively less vulnerable species occurring upward toward the least vulnerable (climax) species. These indicator species are combined with all possible dominants of that particular vegetation layer. This series of possible combinations results in a triangular matrix. (See succession classification section for further explanation.)

3. A tentative key was constructed according to the structure of the classification diagrams (see tables 2, 7, 18), and the tree, shrub, and herb layer of each plot were then classified by layer type according to the appropriate key.

4. Stand data were assembled in synthesis tables (Mueller-Dombois and Ellenberg 1974) to show the early seral-to-climax arrangement of layer types (grouped stands) and layer groups (grouped layer types) resulting from step 3. These tables were studied in detail to ensure that declines and increases in key species followed logical successional patterns (derived from field observations) both within layer groups and between groups. Where illogical patterns appeared, individual stands in the synthesis tables were rearranged so that familiar seral species showed logical relative declines in canopy coverage and so the climax species showed stable or increasing coverages. Occasionally, the order of layer groups was changed to reflect the relative vulnerability of indicator species as suggested by the data.

5. For the shrub and herb layers, polar ordinations (Bray and Curtis 1957; Pfister and Arno 1980) were used to arrange the stands graphically on a quantitative basis of species composition and coverage. The ordinations were compared to the general pattern of stand groupings for that particular layer in the revised synthesis tables. Stands showing major discrepancies were considered for regrouping.

6. Following the previous adjustments, constancy and average cover values (from midpoints of coverage classes) were calculated for those species capable of achieving high constancies or high coverages. The classification diagram and key were adjusted to reflect the final stand groupings in each vegetation layer.

7. The resulting classification was field tested in subsequent field seasons but may need additional field testing for accuracy and completeness. New successional indicators may be encountered because the full environmental range of ABGR/VAGL may not have been sampled and the full successional range due to the many possible disturbances such as thinnings, insect attacks, and underburns may not have been sampled. If new indicators are found, they can be lumped with an ecologically similar indicator that already occurs in the classification diagram or the existing diagram can be expanded to accommodate the new indicator.

THE ABGR/VAGL HABITAT TYPE

Distribution and Description

The ABGR/VAGL h.t. occurs mainly in west-central Idaho (fig. 1) but extends into eastern Oregon (Johnson and Simon 1985). It is most common in drainages of the North Fork Payette and Weiser Rivers and occurs on both granitic and volcanic substrates. ABGR/VAGL is most commonly found between 5,200 and 6,200 feet (1,585 and 1,890 m) in elevation but can extend to as low as 4,500 feet (1,732 m) along cold air channels and upward to 6,500

Figure 1—Distribution of ABGR/VAGL h.t. in Idaho.

feet (1,982 m) on slopes that shed cold air. Within this elevational range, the ABGR/VAGL h.t. reflects a relatively cool, moist environment that occurs mainly on northwesterly to northeasterly aspects. Adjacent cooler sites occur mostly in the subalpine fir series; adjacent warmer sites are usually grand fir/white spirea h.t.; adjacent warmer sites with more moisture are usually grand fir/mountain maple h.t. Although most sites in ABGR/VAGL support *Pseudotsuga* as a major seral species, other tree species may be more important where ABGR/VAGL approaches these other habitat types (table 1).

The early seral conditions found in ABGR/VAGL reflect most of the diversity of site history and site variability within the habitat type. For instance, *Pinus contorta* tends to colonize disturbed sites in frost pocket situations, whereas *Ceanothus velutinus* dominates severely burned areas that are not in frost pockets. *Carex rossii* and *Ribes*

Table 1—Successional role of tree species in ABGR/VAGL h.t. (revised from Steele and others 1981)

ADP No.	Tree species	Abbrev.	Role[1]	Occurrence
001	*Abies grandis*	ABGR	C	Occurs throughout
002	*Abies lasiocarpa*	ABLA	(c)	Cooler sites
007	*Picea engelmannii*	PIEN	(S)	Cooler, moist sites
016	*Pseudotsuga menziesii*	PSME	S	Occurs throughout
013	*Pinus ponderosa*	PIPO	(S)	Warmer sites
006	*Larix occidentalis*	LAOC	(S)	Moist sites
010	*Pinus contorta*	PICO	(S)	Cooler, frosty sites
014	*Populus tremuloides*	POTR	s	Occurs throughout

[1]C = major climax S = major seral
c = minor climax s = minor seral
( ) = occurs in part of the h.t.

viscosissimum tend to dominate scarified areas. *Ribes lacustre* appears mainly in the moister scarified areas that may eventually support *Alnus* and *Picea*. *Potentilla glandulosa* tends to dominate the drier scarified areas and sites that are repeatedly grazed. *Epilobium angustifolium* appears where the soil has been loosened and exposed. These disturbances and consequent vegetative reactions often appear in a mosaic on individual sites and present the field observer with a perplexing array of variability. These mosaics are best interpreted through repeated observations of larger, more uniform areas where the vegetation has reacted to a single identifiable site treatment.

In midseral conditions, tree composition is often diverse. *Pseudotsuga* is common throughout ABGR/VAGL. *Pinus ponderosa* is common in warmer portions of the habitat type and *P. contorta* can dominate in the colder portions, especially where cold air accumulates. *Picea* can dominate wetter portions of the habitat type, and *Larix* becomes increasingly prevalent northward in the ABGR/VAGL distribution. In the shrub layer, *Salix scouleriana* and *Spiraea betulifolia* often accompany the more shade-tolerant components, *Lonicera* and *Vaccinium*. *Alnus sinuata* may appear on the wetter sites that can support *Picea*. Herbs, too, are more numerous in midseral stages and often include *Castilleja*, *Fragaria*, and high coverages of *Arnica* or *Calamagrostis*.

In late seral-to-climax conditions, ABGR/VAGL supports nearly pure stands of *Abies grandis* or *Abies-Picea* mixtures; occasionally *A. lasiocarpa* is also present in response to the cool temperatures on these sites. In the undergrowth, *Vaccinium* achieves dominance through its rhizomatous habit, which enables it to outcompete its common nonrhizomatous associate, *Lonicera*. Species composition of the herb layer varies considerably but coverages tend to be low; *Thalictrum occidentale* or *Calamagrostis rubescens* usually dominates the herb layer.

SUCCESSIONAL FEATURES

Succession Classification

A systematic classification of seral vegetation within the ABGR/VAGL h.t. was developed as part of this study. The basic approach (Steele 1984) is to recognize the two primary factors affecting vegetal change: time and environment. Environmental variation has been categorized by the habitat type classification system (Steele and others 1981). The habitat type system uses indicator species according to their ability to dominate or at least maintain their population at climax. The relative value of a species as an indicator depends on that species' relative environmental amplitude, which is inversely related to indicator value.

Temporal variation within habitat types can be categorized by a similar system that uses indicator species according to their ability to dominate a seral stage. This system of classification depends on a species' relative successional amplitude (relative vulnerability to successional replacement) which is also inversely related to indicator value. Seral indicator species in a given habitat type can be arranged along the successional gradient according to their relative successional amplitudes. Figure 2 shows an example of this arrangement for the major tree species in ABGR/VAGL. These indicators are then combined with possible dominant species to provide a temporal-structural framework for classifying seral vegetation. Figure 3 shows the classification framework derived from figure 2. In contrast, if time is used on a yearly scale to classify seral communities, the relationship becomes untenable due to the randomness of successional forces such as seed crops, insects, disease, weather, and necessary combinations thereof.

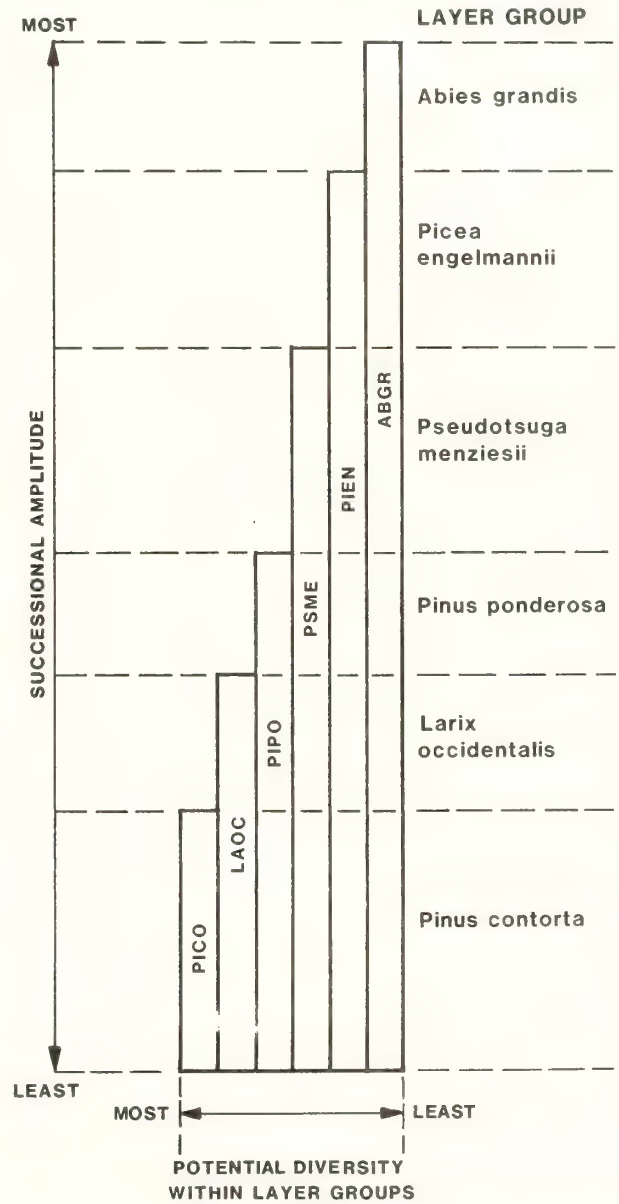


Figure 2—Relative successional amplitudes of major tree species in ABGR/VAGL h.t.

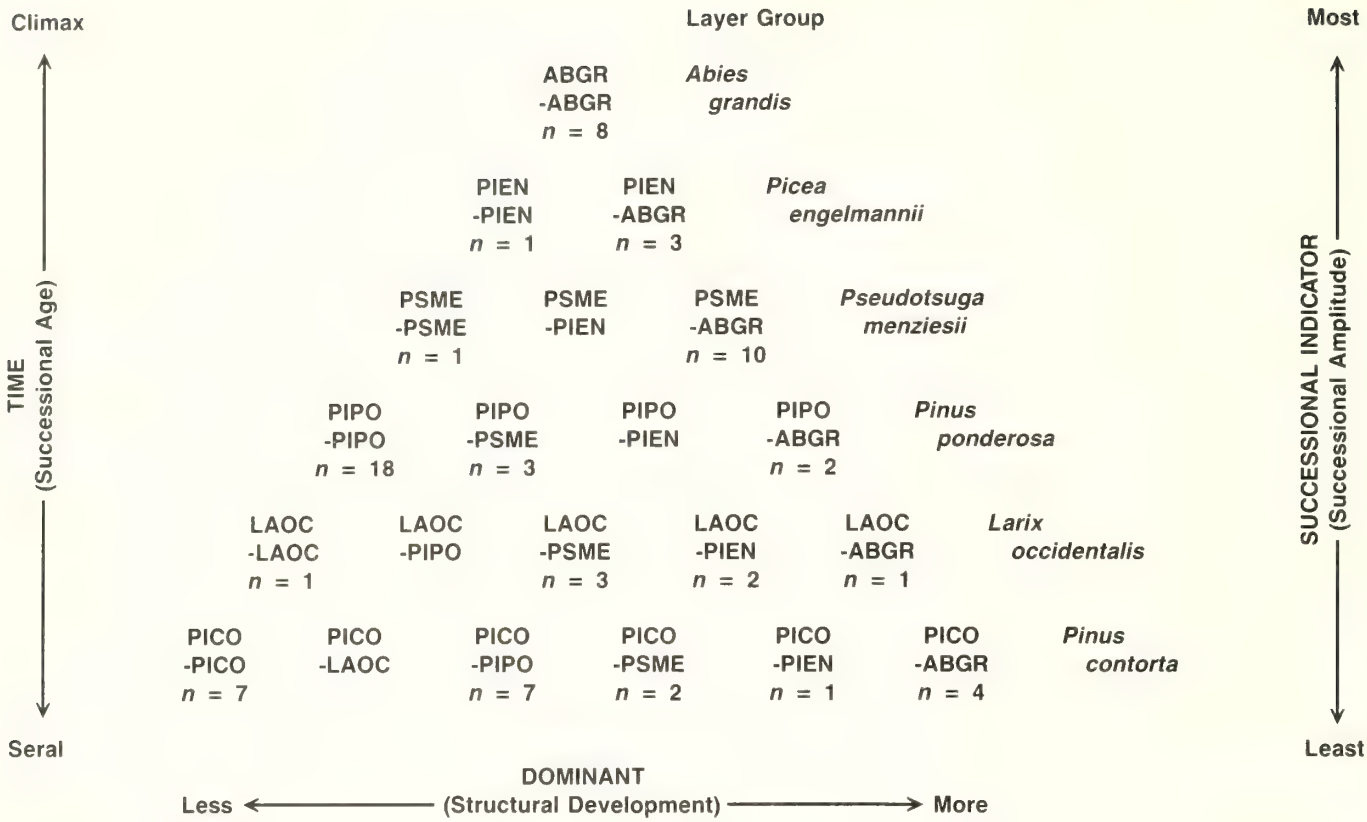


Figure 3—Example of succession classification framework using the tree layer in the ABGR/VAGL h.t. (*n* = number of samples in each layer type).

The Tree Layer

Because the tree, shrub, and herb layers follow partially independent successional patterns at different rates and may be affected by layer-specific disturbance, this classification focuses on the individual layers. The tree layer (trees over 4.5 feet [1.4 m] tall) in ABGR/VAGL contains six major species. Relative successional amplitudes of these species are shown in figure 2 with *Pinus contorta* having the least amplitude. Although *P. contorta* is more shade tolerant than *P. ponderosa* or *Larix* (Minore 1979), it has a shorter life span and achieves less height growth. Thus *P. contorta* is not likely to maintain itself beneath *Larix* or *P. ponderosa* unless some form of disturbance periodically creates a new seedbed for *P. contorta* and reduces the young *Pseudotsuga* or *Abies* that will accumulate in the understory. The relative amplitudes of *Larix* versus *P. ponderosa* are less clear, but the narrow crown and shorter life span of mature *Larix* would seem to favor *P. ponderosa* during succession. Likewise *P. ponderosa* is not apt to survive beneath the denser canopy of *Pseudotsuga*. Once the older pines in the stand have died, another successional segment is delineated. The passing of each of these species marks a segment in the successional sequence. *Abies grandis*, being the most shade tolerant, has the greatest successional amplitude and acts as the climax tree. Although various factors often preclude the entire replacement sequence, the relative successional amplitudes have been established for classification purposes.

Figure 2 suggests that possible diversity of the tree layer is greatest in the early seral stages. Here all six species could be present on the site, although usually this is not the case. In the climax stage, however, only *A. grandis* will be well represented, with all other tree species poorly represented or absent. Diminishing diversity during secondary succession becomes more apparent in the shrub and herb layer classifications where more species occur.

Figure 3 shows the various seral conditions in the tree layer that may converge to a common climax community of *A. grandis*. *Pinus contorta* forms the base of the triangle because it has the least successional amplitude. Other species are arranged in ascending order as a reflection of their progressively greater successional amplitudes. No single attribute, such as relative shade tolerance (Minore 1979) corresponds directly with all successional amplitudes because other factors may be involved and relative amplitudes reflect the integrated effects of all autecologic attributes influenced by succession.

In order to maintain a systematic taxonomic structure, each unit in figure 3 is called a layer type and each group of layer types having the same seral indicator is called a layer group. Layer groups denote the various seral stages that are possible within a given habitat type or phase. Layer types within one layer group such as PIPO-PIPO, PIPO-PSME, PIPO-PIEN, and PIPO-ABGR in the PIPO layer group (fig. 3) denote, in a general way, the structural conditions that are possible in that particular seral stage. These conditions may result from natural establish-

ment of tree seedlings or from tree plantations which often result in a given layer type (especially PIPO-PIPO). A layer type may vary structurally because more than two tree species may be codominant, although usually this is not the case. Potential variability within layer types is similar to the potential diversity within layer groups as shown in figure 2. Because this classification always uses the earliest seral species in terms of both the seral indicator and the dominant, one can assume that later seral or climax species may be present in the stand. Similar classifications were developed for the shrub and herb layers. If desired, taxonomy of the tree, shrub, and herb layers can be combined to characterize the entire plant community.

Delineating the vertical axis (time) into layer groups (fig. 3) provides an ecological basis for segmenting the successional time-sequence. As time progresses, a stand's classification status may progress from one layer group to a successionally older layer group. For instance, *P. ponderosa* (well represented) may dominate the tree layer (PIPO-PIPO) or may be dominated by *Pseudotsuga* (PIPO-PSME) or *A. grandis* (PIPO-ABGR). But the presence of *P. ponderosa* can always be interpreted as a specific segment of the succession sequence because the potential to be outcompeted by *Pseudotsuga* always exists. *Pinus ponderosa* is unable to replace *Pseudotsuga* without the aid of disturbance but can always outcompete *P. contorta*.

Figure 3 serves as a **classification diagram** (not a succession model) for seral tree layers in ABGR/VAGL h.t. These and the other diagrams herein do not outline actual succession sequences for a given site but rather illustrate the possibilities within the habitat type. Actual successions skip many layer types and even layer groups within their respective diagrams. A succession sequence can be described in terms of the layer types shown, but is determined by species composition of the stand and available seed sources.

Figure 3 also serves as a basis for constructing a simple key to tree layer types for field use. This is done by starting with the earliest layer group in figure 3 and progressing along the time gradient to climax (table 2). Keys to the shrub and herb layer types are constructed the same way. These keys are intended to be used in the same manner as the habitat type keys (Pfister and others 1977; Steele and others 1981).

Table 2—Key to tree layer groups and layer types, with ADP codes, in ABGR/VAGL h.t.

		ADP codes
1. *Pinus contorta* well represented[1] (Choose first condition that fits)	PICO Layer Group	010
1a. *Pinus contorta* dominant	PICO-PICO Layer Type	010.010
1b. *Larix occidentalis* dominant or codominant	PICO-LAOC Layer Type	010.006
1c. *Pinus ponderosa* dominant or codominant	PICO-PIPO Layer Type	010.013
1d. *Pseudotsuga menziesii* dominant or codominant	PICO-PSME Layer Type	010.016
1e. *Picea engelmannii* dominant or codominant	PICO-PIEN Layer Type	010.007
1f. *Abies grandis* dominant or codominant	PICO-ABGR Layer Type	010.001
1. *P. contorta* poorly represented	2	
2. *Larix occidentalis* well represented (Choose first condition that fits)	LAOC Layer Group	006
2a. *Larix occidentalis* dominant	LAOC-LAOC Layer Type	006.006
2b. *Pinus ponderosa* dominant or codominant	LAOC-PIPO Layer Type	006.013
2c. *Pseudotsuga menziesii* dominant or codominant	LAOC-PSME Layer Type	006.016
2d. *Picea engelmannii* dominant or codominant	LAOC-PIEN Layer Type	006.007
2e. *Abies grandis* dominant or codominant	LAOC-ABGR Layer Type	006.001
2. *L. occidentalis* poorly represented	3	
3. *Pinus ponderosa* well represented (Choose first condition that fits)	PIPO Layer Group	013
3a. *Pinus ponderosa* dominant	PIPO-PIPO Layer Type	013.013
3b. *Pseudotsuga menziesii* dominant or codominant	PIPO-PSME Layer Type	013.016
3c. *Picea engelmannii* dominant or codominant	PIPO-PIEN Layer Type	013.007
3d. *Abies grandis* dominant or codominant	PIPO-ABGR Layer Type	013.001
3. *P. ponderosa* poorly represented	4	
4. *Pseudotsuga menziesii* well represented (Choose first condition that fits)	PSME Layer Group	016
4a. *Pseudotsuga menziesii* dominant	PSME-PSME Layer Type	016.016
4b. *Picea engelmannii* dominant or codominant	PSME-PIEN Layer Type	016.007
4c. *Abies grandis* dominant or codominant	PSME-ABGR Layer Type	016.001
4. *P. menziesii* poorly represented	5	
5. *Picea engelmannii* well represented (Choose first condition that fits)	PIEN Layer Group	007
5a. *Picea engelmannii* dominant	PIEN-PIEN Layer Type	007.007
5b. *Abies grandis* dominant or codominant	PIEN-ABGR Layer Type	007.001
5. *P. engelmannii* poorly represented	6	
6. *Abies grandis* well represented	ABGR Layer Group	001
6a. *Abies grandis* dominant	ABGR-ABGR Layer Type	001.001
6. *A. grandis* poorly represented	depauperate or undescribed tree layer or not ABGR/VAGL h.t.	

[1] "Well represented" means canopy coverage ⩾5 percent regardless of diameter classes of the trees involved. Trees less than 4.5 feet (1.4 m) tall should be omitted from coverage estimates. "Dominant" refers to greatest canopy coverage, "codominant" refers to nearly equal canopy coverage. When keying to layer type, choose first condition that fits.

SIZE CLASS NOTATIONS

The basic classification approach used in the tree, shrub, and herb layers is presented in figures 2 and 3 and table 2, but because the tree layer progresses through recognizable size classes of development such as sapling (0.1-4 inches, 0.25-10.2 cm d.b.h.), pole (4-12 inches, 10.2-30.5 cm), mature (12-18 inches, 30.5-45.7 cm), and old-growth (>18 inches, 45.7 cm), these additional subdivisions should be noted. These notations are best added to each tree species after the tree layer type (l.t.) is identified, such as, mature PIPO-sapling PSME l.t. For consistency, the smallest size class that is well represented should be noted for the successional indicator because it usually reflects the most recent regeneration of that particular species. For the dominant species, the dominant size class should be used. When the indicator species is well represented in the stand but not in any one size class or the dominant species does not have a dominant size class, the size class with the most coverage should be noted. For convenience, size class notations can be abbreviated as follows: s. - sapling; p. - pole; m. - mature; and o.g. - old-growth.

It may be difficult, at first, to visualize some tree layer types in their appropriate successional position. For instance, an s. ABGR - s. ABGR l.t. may not seem to be successionally older than an m. PICO - s. PSME l.t., because we normally think of time-related situations on a yearly scale. On a successional scale, however, a pure stand of sapling *A. grandis* is closer to climax than a mixed older stand of *P. contorta* and *Pseudotsuga* because it will not go through the earlier successional stages of the PICO and PIPO layer groups. In fact, an s. ABGR - s. ABGR l.t. may even reach climax in fewer years because no species replacement (succession) is needed, whereas an m. PICO - s. PSME l.t. must first lose the *P. contorta* and if *Larix* or *P. ponderosa* is well represented must also pass through a LAOC-PSME or PIPO-PSME l.t. as well as a PSME-ABGR l.t. before reaching climax.

The six possible tree layer groups in ABGR/VAGL (fig. 3) are described below and delineate tree layer succession into relatively broad segments. Because layer groups are usually delineated by a single indicator species, their origin can be related to a somewhat consistent set of site conditions. But progression from one layer group to another (and one layer type to another) depends on composition of the individual stand and, therefore, is predictable only from field observation. The following layer group descriptions are presented in the order they appear in the key (table 2). Constancy and average coverage of species within sampled layer types appear in appendix A.

PINUS CONTORTA LAYER GROUP (PICO L.G.)

Pinus contorta occurs frequently in ABGR/VAGL, but becomes most abundant in cooler portions of the habitat type. Where *P. contorta* is a dominant species, it generally indicates a frost pocket condition and is usually the tree species most capable of regenerating the site. In some cases the pattern of clearcuts in the area has increased the frost pocket effect, leaving *P. contorta* to dominate sites where other species were once able to establish (fig. 4). Historically, severe wildfires were the cause of the PICO l.g., but more recently, clearcuts with burning or scarification have produced a similar result.

In ABGR/VAGL, PICO layer types represent the earliest seral stages of the tree layer and are often found as sapling or pole-size stands (fig. 5). The relatively short-lived nature of *P. contorta* allows this layer group to be replaced in a relatively short time. Most sampled stands in the PICO l.g. will progress directly to the PSME, PIEN, or ABGR l.g.; a few will progress to the PIPO l.g. Progression to the LAOC l.g. appears to be rare.

LARIX OCCIDENTALIS LAYER GROUP (LAOC L.G.)

Larix occidentalis occurs sporadically in the ABGR/VAGL h.t. and is usually most abundant on the moister sites that support *Picea*, *Alnus*, and *Ribes lacustre*. In central Idaho, *Larix* extends its range southward primarily in the ABGR/VAGL h.t. Its southern limit as an important timber species occurs near Smith's Ferry, ID. Occasional trees occur southward to Garden Mountain northeast of Banks, ID (Bruna 1984). Although old-growth *Larix* are often present in older stands in ABGR/VAGL, *Larix* was seldom found as a major component of naturally established sapling or young pole-size stands. Reasons for the sparse establishment of *Larix* are not clear but may relate to the fact that *Larix* is near its southern limits in ABGR/VAGL. Historically, the LAOC l.g. reflects severe disturbance from wildfire. Yet clearcuts with broadcast-burn or scarification treatments have resulted in only small amounts of *Larix* regeneration. Reduction of seed sources through timber harvest and possibly a marginal environment for natural establishment of *Larix* seedlings may be responsible for lack of *Larix* in clearcuts. With the older stands being rapidly harvested and fire control becoming increasingly effective, the southernmost populations, and possibly ecotypes, of *Larix* could become extirpated. Yet on some sites, planting *Larix* in a mixture with other tree species would enhance stand structure and diversity.

The LAOC l.g. is relatively rare in ABGR/VAGL. Of the seven stands encountered, four are apparently progressing toward the PSME l.g., one toward the PIPO l.g., and one toward the PIEN l.g. The seventh stand was a young *Larix* plantation with no successional sequence yet apparent.

PINUS PONDEROSA LAYER GROUP (PIPO L.G.)

Pinus ponderosa is a major seral tree of ABGR/VAGL but does not always establish readily following disturbance. Lack of seed and unsuitable seedbeds often limit pine regeneration. Distance to seed source, poor dispersion of the heavy seed, and infrequent seed crops appear mainly responsible for lack of seed in large clearcuts. *Carex geyeri*, *Calamagrostis*, and several shrubs are stimulated by burning or logging and can quickly dominate potential seedbeds. As a result, natural establishment of *P. ponderosa* is often slow and sporadic, but well-scarified sites beneath a light canopy of seed-producing pine should regenerate a PIPO layer type provided the site is not moist enough to support *Alnus sinuata*. A high density of

Figure 4—A sapling PICO - sapling PICO tree layer type southeast of Smith's Ferry, ID. This site was clearcut and broadcast burned 15 years ago. It was planted unsuccessfully to *Pseudotsuga* the following year. The pattern of clearcuts in this area increased the frost pocket effect and likely enhanced the opportunity for *Pinus contorta* establishment. *Pinus contorta* colonized the site from a nearby seed source and is now the dominant tree.

Figure 5—A dense pole PICO - pole PIEN tree layer type northwest of New Meadows, ID. The many fallen stems of *Pinus contorta* suggest that the pine once dominated this site. *Pinus contorta* is still well represented, but the more shade tolerant *Picea engelmannii* is now the dominant tree. No other tree species is well represented. As the pine continues to decline, this stand will progress to a PIEN-PIEN tree layer type.

Picea or *Ribes lacustre* or the presence of *Actaea* or *Alnus* are likely indicators of potential alder sites. The alder colonizes bare soil from windblown seed and may outcompete the pine seedlings. Although occasional pines may be present on these alder sites, attempts to establish stands of pine naturally, and possibly by planting, may not succeed.

The PIPO l.g. occurs in much of the ABGR/VAGL h.t. except in frost pockets and other relatively cool sites. Naturally established sapling to pole-size stands in the PIPO l.g. are rare; most are plantations (fig. 6). Scattered mature to old-growth trees are common and reflect a history of fire but stands dominated by older *P. ponderosa* are scarce. Because *P. ponderosa* is relatively long-lived, this layer group is one of the more persistent seral conditions in ABGR/VAGL. Most of the sampled stands appear to be progressing toward the PSME l.g.

PSEUDOTSUGA MENZIESII LAYER GROUP (PSME L.G.)

Pseudotsuga is the most common seral tree in ABGR/VAGL, yet it rarely dominates following clearcutting. Plantings of *Pseudotsuga* have been tried in ABGR/VAGL but few have succeeded. Causes of failure are not well documented, yet many sites in ABGR/VAGL appear suitable for *Pseudotsuga* plantations. Established *Pseudotsuga* seedlings often appear to have benefited from a protected seedling microsite. Rocks, logs, and shrub and tree canopies all provide microsite protection. Most natural stands of *Pseudotsuga* apparently established under the shelter of trees or shrubs.

Stumps and fallen logs suggest that all sampled stands in the PSME l.g. progressed from the PICO, LAOC, or PIPO layer groups. Three of these stands will likely become a PIEN l.t.; the remainder are progressing directly to ABGR-ABGR. In several stands, selective cutting of the pines and larch has accelerated succession into the PSME l.g.

PICEA ENGELMANNII LAYER GROUP (PIEN L.G.)

Picea engelmannii is considered relatively shade tolerant and a late seral to near climax species in ABGR/VAGL. Although *Picea* may appear throughout much of the habitat type, its best development occurs at the moist extreme where *Alnus, Ribes lacustre*, or *Actaea rubra* are

Figure 6—A well-stocked sapling PIPO - sapling PIPO tree layer type east of Cascade, ID. This area was clearcut and well scarified 19 years ago. It was successfully planted to *Pinus ponderosa* the following year. Now the pine clearly dominates the site. Trace amounts of *Pinus contorta*, *Pseudotsuga*, and *Abies grandis* have established naturally.

evident. The litter and duff from *Picea* inhibit germination and growth of certain conifers, particularly *Picea, Pseudotsuga,* and *Pinus contorta.* One study (Daniel and Schmidt 1971) suggests that fungi living in the duff inhibit seedlings of these tree species while another study (Taylor and Shaw 1982) implicates allelopathic chemicals (tannins and stilbenes) as the inhibitory agent. Whatever the cause, a mineral-soil seedbed is clearly essential for achieving adequate regeneration of *Picea, Pseudotsuga,* and *P. contorta* wherever large *Picea* now stand.

The PIEN l.g. contains two layer types, both of which were sampled (fig. 3). All of these samples were mature to old-growth stands, reflecting the long fire-free interval needed for spruce development. Successionally, these stands tend to be quite persistent but eventually progress to the ABGR l.g.

ABIES GRANDIS LAYER GROUP (ABGR L.G.)

Abies grandis is the most shade-tolerant tree that can dominate in the ABGR/VAGL h.t. and hence acts as the climax indicator. As a result, the ABGR l.g. often occurs as a mature or old-growth stand under natural conditions (fig. 7). Selective logging or clearcutting with no site preparation, however, can produce the ABGR l.g. in sapling or pole stages. Such results may leave little opportunity for the seral, and more commercially desirable, trees to establish. Although logging has converted an old-growth stand to saplings or poles, actual succession of the tree layer may have been accelerated to the ABGR l.g. In these situations, additional site treatment will be needed to obtain more commercially desirable tree species. Seral species may also be more ecologically desirable in terms of maintaining a healthy and more fire-resistant stand. Compared to other tree layer types in ABGR/VAGL, ABGR-ABGR l.t. has the greatest hazard potential for catastrophic fire, insects (spruce budworm), and disease (heart rot). If all fire, insect, and disease hazards, including decay, could be measured on a common scale between habitat types, maximum hazard potentials in climax tree layer types may be axiomatic.

MANAGEMENT IMPLICATIONS

The following implications for management of the tree layer were derived from data and repeated field observations taken during this study and the habitat type study (Steele and others 1981). Users of the following information should keep in mind the often small sample size of the

Figure 7—A pole ABGR - mature ABGR tree layer type in the Lost Creek drainage west of New Meadows, ID. This nearly pure stand is dominated by mature *Abies grandis* with pole-size *Abies* well represented. Scattered dead standing and fallen stems of *Pinus contorta* suggest a previous tree layer composition of PICO-ABGR.

data set and the minimal amount of field testing and user response. Yet trends reflected by these data appear logical and seem adequate to support interpretations on a relative basis.

Pocket Gophers—It has long been known that pocket gophers (*Thomomys talpoides*) can damage pine plantations (Moore 1943; Dingle 1956). Reasons for this damage have been studied at length. In summarizing gopher-related studies, Teipner and others (1983) suggest that gopher damage to young pines may be related to amount and composition of associated plant species as well as gopher density. Our studies indicate that species composition can vary with type of site preparation prior to tree planting which, in turn, may influence gopher populations. Therefore pocket gopher mounds were tallied (Richens 1965) in our sample plots and then summarized by site treatment.

Most sites in ABGR/VAGL had few or no gopher mounds, but a notable increase in gopher mound occurrence was found on sites that had been scarified without burning. About 20 percent of the partially cut stands and 33 percent of the clearcuts that had been scarified without burning had gopher activity, whereas all other site conditions had virtually none (table 3). Gopher activity is also more evident on unburned scarified sites in several other habitat types (Steele and Geier-Hayes 1984, 1985, 1986).

Table 3—Occurrence of pocket gopher mounds following various site disturbances in ABGR/VAGL h.t.

Site treatment	Number of sites	Mound occurrence[1]
Clearcut, broadcast burned, or stand destroyed by wildfire	4	0(0) - 0(24)
Clearcut, broadcast burned, and scarified	4	0(0) - 0(12)
Clearcut and contour terraced	5	0(0) - 0(14)
Clearcut, unburned, and scarified	30	33(284) - 12(12)
Partial cut and scarified	5	20(225) - 22(21)
Clearcut and no site preparation	4	0(0) - 0(10)
Uncut stands, no site preparation	18	5(30) - 53(74)

[1]Expressed as: percentage constancy (average number/acre) - average years since disturbance of sites with mounds (of sites without mounds).

The gophers, of course, do not respond directly to the site treatment but rather to the vegetation resulting from the treatment. Scarification, either by machines or heavy livestock use, is most apt to generate early seral herbaceous layers which likely stimulate gopher populations. In contrast, burning without scarification often results in a dense shrub layer and thus a depauperate herb layer. Burning may also result in herb layers that are less appealing to gophers. (See herb layer section for further discussion.)

Planted Tree Establishment—Planted sites were identified from plantation signs and obvious rows of even-aged trees. Seedling survival was estimated in percentage and recorded for each site preparation technique. Site preparation included no preparation, hand scalps, scarification with and without burning, and contour terraces. Hand scalping was grouped with no preparation because it usually did not reduce long-term competition and because it could not always be recognized in older plantations. Scarification treatments usually resulted from stripping, pile and burn operations, or extensive machinery traffic during the logging. Sometimes broadcast burns were also applied following the logging operation. Scarification treatments are uncommon, however, on many of the steeper slopes associated with this habitat type. Contour terraces varied in width from 2 to 3 feet on gentle terrain to 6 to 8 feet on the steeper slopes. The wider terraces were more widely spaced on the slope so as to reduce erosion. Contour ditches appear to have the same effect on tree growth and survival as contour terraces and so were grouped with that treatment.

Survival of planted *Pinus ponderosa* (table 4) was greatest (about 82 percent after 16 years) on contour terraces and about equally successful (79 percent after 9 years) on

Table 4—Success of tree plantations by site treatment in ABGR/VAGL h.t.

Tree species	Site treatment[1]: None includes hand scalps	Broadcast burning	Scarified unburned, includes stripping	Contour terraces, includes ditching
	Survival of plantings, percent (average age)[2]			
PICO	—	—	99(14) *n* = 1	80(19) *n* = 1
LAOC	—	—	?(10) *n* = 1	—
PIPO	30(14) *n* = 1	65(18) *n* = 1	79(9) *n* = 6	82(16) *n* = 6
PSME	—	1(13) *n* = 1	23(10) *n* = 6	50(6) *n* = 2
PIEN	—	—	—	80(11) *n* = 1
	Average age to breast height, years			
Planted[3]				
PICO	—	—	9 *n* = 1	9 *n* = 1
LAOC	—	—	6 *n* = 1	—
PIPO	—	10 *n* = 1	8 *n* = 18	7 *n* = 6
PSME	—	—	9 *n* = 8	—
PIEN	—	—	10 *n* = 1	11 *n* = 1
Natural				
PICO	—	6 *n* = 3	8 *n* = 7	8 *n* = 4
LAOC	—	—	7 *n* = 4	—
PIPO	—	9 *n* = 1	9 *n* = 2	—
PSME	—	—	—	14 *n* = 1
ABGR	—	—	12 *n* = 3	20 *n* = 1

[1]*n* = number of sample sites.
[2]Plantings less than 4 years old were omitted; complete plantation failures and multispecies planting could not be sampled for survival.
[3]Nursery years are not included.

sites that had been scarified but not burned. These treatments minimize potential shrub competition for many years by removing seed and some root crowns from the site, whereas burning encourages certain shrubs to germinate from buried seed or resprout from existing root systems. Broadcast burning results in a dense shrub cover relatively quickly and in a few years creates situations for which *Pseudotsuga* is better adapted than *P. ponderosa*. The *Pseudotsuga*, being more shade tolerant than pine, is not as adversely affected by shrub development in later years. In early years, the shrub canopy may even provide critical protection for *Pseudotsuga* seedlings.

The survival percentages in table 4 may differ considerably from Ranger District records for two reasons. First, the data reflect planting attempts over many years and many early planting failures were due to factors other than site treatment and habitat type. Second, the data reflect plantation success over the past 10 to 20 years, whereas District records are generally maintained for only a few years after planting and do not always reflect the full effects of the site and long-term competition. Our figures are not necessarily the highest possible survival rates because occasionally high survival has been achieved in most treatment categories. Our survival rates are best interpreted as relative probability of success rather than percentage of survival.

Age to Breast Height—The years required for a tree to reach breast height (4.5 feet, 1.4 m) is a critical factor in estimating growth and yield parameters of forest stands as well as seedling success against competing vegetation. Normally an estimated constant is used for a given species regardless of site. Yet for some species, sample data have shown considerable variability in breast height ages between habitat types and even between site treatments within a habitat type. In ABGR/VAGL, breast height age for planted *Pinus ponderosa* is about 7 to 8 years regardless of site treatment (table 4). In the drier Douglas-fir/ninebark and Douglas-fir/pinegrass habitat types, age to breast height of pine could be reduced 2 to 3 years by planting on contour terraces (Steele and Geier-Hayes 1983, 1984). This does not appear to be the case in the wetter grand fir/mountain maple (Steele and Geier-Hayes 1985) or ABGR/VAGL h.t.'s, which suggests that terraces improve the moisture regime for pine on drier sites but may have little benefit on sites with adequate moisture.

Snow Damage to Pine Plantations—Extensive snowpack damage to ponderosa pine plantations was previously noted in the grand fir/mountain maple habitat type (Steele and Geier-Hayes 1985) and led to an assessment of similar damage in ABGR/VAGL. The damage is sustained mainly by trees greater than 4 to 5 feet (1.2 to 1.5 m) tall. It varies from stripped lateral branches and bent terminals to permanent 90-degree angles in the main stem and entire saplings pushed into semiflattened positions. Stem internodes indicate that, once damaged, the pine's growth rate is reduced for a year or more, making the young tree more vulnerable to shrub competition (fig. 8). With *Pinus contorta*, Rehfeldt (1987) noted a similar loss in growth rate of 22 percent. Long-term snow records suggest that subsequent damage may occur about every 4 years, causing accumulated deformities. In spring, these bent, stunted trees remain beneath the snow longer than undamaged trees and during prolonged snowmelt can suffer increased mortality from the brown-felt blight (*Neopeckia coulteri*).

Most pine plantations situated below 5,500 feet (1,676 m) in elevation escape serious snow damage regardless of aspect or slope. Nevertheless, the main stems and side branches may be temporarily deformed, particularly on westerly aspects. As elevation increases from 5,500 to about 5,800 feet (1,676 to 1,768 m), damage potential also increases. But damage may be less severe on north aspects (between 340 and 20 degrees) or under certain site conditions described below. Slope steepness is a relatively minor variable because most slopes in ABGR/VAGL are steep enough to cause snow movement. Above 5,800 feet (1,768 m) snow damage is apt to occur on any aspect but can be alleviated by certain conditions. For instance, pine plantations near ridgetops may escape snow damage within the hazard zone outlined above. Likewise, plantations that are well shaded in early spring by a nearby ridge or adjacent old-growth stand may escape damage. Damage-free plantations were found as high as 5,900 feet (1,798 m) regardless of aspect under these circumstances. Sites with high stumps and large logs or boulders can also reduce snow hazards. Proper location and treatment of cutting units can exploit these advantages where high damage potential exists. Where the risk cannot be alleviated, plantings of *Pseudotsuga* and *Larix*, although they may have lower survival than pine initially, can sustain greater snow-bending and may prove more successful than pine over the long term.

In contrast, potential snow damage can be increased to as low as 4,300 feet (1,311 m) by contour terraces. In steep terrain, these terraces are often quite wide and accumulate more snow than adjacent slopes. Terrace cutbanks create a steepened sliding surface that exacerbates snow movement. The pines planted closest to the cutbank are most apt to be damaged while those nearest the fill slope often escape damage.

Extent of snow damage within plantations can vary from scattered individual trees at lower elevations to virtually all trees at the upper elevations. Trees having only light damage (bent terminals) generally recover as described by Oliver (1970) unless repeatedly damaged. Severely damaged trees probably could recover but are usually situated so as to receive repeated snow damage, making full recovery unlikely.

Proper genetic seed source is a critical factor in snow damage susceptibility and recovery (Rehfeldt and Cox 1975). In general, plantations from lower elevation seed sources are not apt to grow successfully in the snow hazard zone, whereas trees from appropriate seed sources tend to sustain less damage and recover more readily. At upper elevations of the snow hazard zone, however, even pine plantations of the proper seed source may experience reduced stocking levels and lower growth rates. Recognizing snow damage potential may be difficult in some situations, but it is an important consideration when planting *Pinus ponderosa* on ABGR/VAGL sites above 5,500 feet (1,676 m) in elevation. For a more detailed approach to predicting snow damage hazards in pine plantations see Megahan and Steele (1987).

Figure 8—A badly snow-damaged plantation of *Pinus ponderosa* in the Squaw Creek drainage north of Ola, ID. These stunted, deformed trees appear to have sustained repeated damage. Loss of height growth has jeopardized these pines' ability to outcompete the dense shrub layer.

Growth and Yield Capability—Height-age data of free-growing trees, usually in clearcuts or burns, were collected during the course of this study. These data provided growth information for the younger age classes of major tree species in ABGR/VAGL. Similar data in older age classes were taken from dominant or codominant trees in old-growth stands during this study and the habitat type classification study (Steele and others 1981). Increment cores of these older trees were examined for evidence of suppression. If the core indicated past suppression or if it was too far from the pith to allow a confident estimate of total age, the tree was rejected. Remaining data were used to estimate site index and yield capability.

Sources for estimating site index and yield capability for the various species are shown in table 5. The *Abies grandis* site index and yield capabilities were derived from Stage (1959) and Brickell (1970), respectively. But, the values were read directly from graphs rather than using equations that require crown ratios, an unavailable input. The *Picea* site index was converted to a 50-year base from Alexander's (1967) *Picea engelmannii* curves; related yield data provided by Alexander (Alexander and others 1975) enabled us to compute spruce yield capability for natural stands as outlined in Steele and others (1981). The *Pseudotsuga* site index was plotted from Monserud's (1985) site curves for *Pseudotsuga* in the *Abies grandis* series, but because no yield tables exist for *Pseudotsuga*, Brickell's (1970) *Pinus ponderosa* yield curve was used. The *Pinus ponderosa* site index and yield capability were derived from Brickell's (1970) site curves which are a conversion to a 50-year base age from Lynch (1958). Site index and yield capability for *Larix* and *Pinus contorta* were derived from Brickell (1970).

The growth and yield capabilities of major tree species in ABGR/VAGL are shown in table 6. *Picea* and *Pinus ponderosa* show about the same yield capability, but these species seldom grow equally well on the same site. *Picea* grows best on the cooler or moister sites that also support *Pinus contorta, Alnus sinuata*, or *Ribes lacustre*. *Pinus ponderosa* shows its best growth on the warmer, better drained sites that lack these species. In old-growth stands of ABGR/VAGL, remnants of the pine or spruce may provide the best clue as to which species is best suited for a particular site. It should be remembered, however, that *P. ponderosa* seldom dominates these sites naturally, and old trees may exist only sporadically on sites having high potential for this species. Also *P. contorta* may easily invade sites having a high potential for *Picea*, but as table 6

Table 5—Sources for estimating site index and yield capability

Species	Years to breast height[1]	Source of site curve[2]	Source of yield capability
Abies grandis	—	Stage 1959	Brickell 1970
Picea engelmannii	—	Alexander 1967	Alexander[3]
Pseudotsuga menziesii	9	Monserud 1985	Used PIPO curve
Pinus ponderosa	8	Lynch 1958	Brickell 1970
Larix occidentalis	7	Brickell 1970	Brickell 1970
Pinus contorta	8	Brickell 1970	Brickell 1970

[1]Where no value is shown, curves based on age at breast height were used.
[2]Site curves with a 100-year index age were converted to a 50-year index age.
[3]Based on data provided by Alexander from Alexander and others (1975) from which a linear regression of yield capability for natural stands was developed (Steele and others 1981). (Yield capability = $-26.0 + 1.84 \times$ 50-year site index, $R^2 = 0.66$.)

shows, some yield capability can be lost by allowing *P. contorta* to dominate these sites. Because *P. contorta* approaches its warm limits in ABGR/VAGL, even well-managed stands of this species may produce less volume than moderately managed stands of the other tree species. Table 6 shows *Abies grandis* as having the highest yield capability, but in ABGR/VAGL the heartwood of *A. grandis* is often infected with Indian paint fungus (*Echinodontium tinctorum*), which markedly reduces merchantable volume.

Table 6—Growth and yield characteristics of trees in ABGR/VAGL h.t.

Tree species	Number of site trees	Site index (50-year base)	Number of stands	Yield capability
				Ft³/acre/year
Abies grandis	12	52 ± 6[1]	12	111 ± 11
Picea engelmannii	8	66 ± 5	8	96 ± 9
Pseudotsuga menziesii	16	61 ± 5	16	82 ± 9
Pinus ponderosa	20	67 ± 4	19	97 ± 12
Larix occidentalis	7	65 ± 7	7	85 ± 16
Pinus contorta	9	59 ± 3	7	73 ± 6

[1]95 percent confidence intervals.

SUMMARY OF TREE LAYER SECTION

In ABGR/VAGL, *Pinus contorta* is considered the least tolerant of succession followed by *Larix*, *Pinus ponderosa*, *Pseudotsuga*, *Picea*, and finally *Abies grandis*. *Pinus contorta* will dominate mainly in frost pocket areas; *Picea* will dominate mainly on the wetter sites that support *Actaea*, *Alnus*, or *Ribes lacustre*. Sometimes these wetter sites are also frost pockets. *Larix* approaches its southern limits in ABGR/VAGL and does not always reestablish readily in suitable seedbeds. *Pinus ponderosa* seldom colonizes large clearcuts due to poor seed dispersal, cyclic cone crops, and rapidly developing shrub competition. *Pseudotsuga* establishes best where the seedling microsite is protected from wind and intense sunlight.

Clearcutting followed by scarification without burning, such as dozer-piling operations, minimizes long-term shrub competition for tree seedlings and results in high survival of planted *P. ponderosa* and *P. contorta*. Unfortunately, this site treatment is the one most apt to increase pocket gopher activity and provide minimal wildlife forage. Contour terracing or ditching also results in high survival of planted pines but may increase *Salix* establishment as well as snow damage hazards to pine plantations.

Clearcutting followed by broadcast burning results in less gopher activity and greater wildlife forage but allows tall-growing shrub species, such as *Salix*, to resprout and suppress planted pines. In contrast to scarification, the shrub layers that result from burning are usually too dense to allow replanting of the site if the first tree planting should fail.

Clearcutting with no site preparation can minimize gopher activity and generate forage for wildlife but provides little opportunity for establishment of pine or larch.

Partial cutting followed by scarification can be used to establish *P. ponderosa*, *Pseudotsuga*, or *Picea* provided the desired seed source exists in the overstory. When a minimal overstory remains, as in a shelterwood for pine, pocket gopher activity may increase.

Potential snow damage to pine plantations increases with elevation starting at about 5,500 feet (1,676 m), especially on westerly aspects. Extent and severity of damage can be reduced by using the proper seed source and leaving high stumps, logs, and boulders on the site. Contour terraces can increase snow hazards. Above 5,800 feet (1,768 m), plantations positioned on minor ridges are most apt to escape snow damage.

Either *Picea* or *P. ponderosa*, depending on site moisture, have the greatest yield capability in ABGR/VAGL. *Abies grandis* is readily infected by heartrot, which can result in high basal areas of unsound wood.

The Shrub Layer

Shrub layer succession in ABGR/VAGL is relatively complex compared to some habitat types in central Idaho. This is due mainly to the greater production potential of these sites, which leads to greater vegetal diversity. Environmental variation within the habitat type also contributes to successional diversity. The dry extreme of ABGR/VAGL generally merges with the grand fir/white spirea habitat type and the moist extreme merges with grand fir/mountain maple. Shrub layer succession near these extremes often resembles that of the adjacent site rather than a modal ABGR/VAGL site.

Relative successional amplitudes of major shrub species in ABGR/VAGL provide the basis for shrub layer classification and are shown in figure 9. These amplitudes were derived from many field observations and sample data (appendix B). They are meaningful only in a relative sense because there is no scale for measurement. Ideally, relative amplitudes should be established through studies of many permanent plots over many decades, but such studies are rare. Consequently, accuracy of relative amplitudes (fig. 9) varies from well-established trends to the authors' best guess. The certainty of this accuracy is greatest for the species farthest apart. For example, *Ceanothus* and *Ribes* clearly have less successional amplitude than *Vaccinium* (fig. 9), but the relative amplitudes of *Symphoricarpos* versus *Rubus* are less certain. Consequently, when determining relative amplitudes one must use the "philosophy of successive approximations" (Poore 1962) as a scientific basis for developing hypotheses for each species followed by testing through field observation and data analysis.

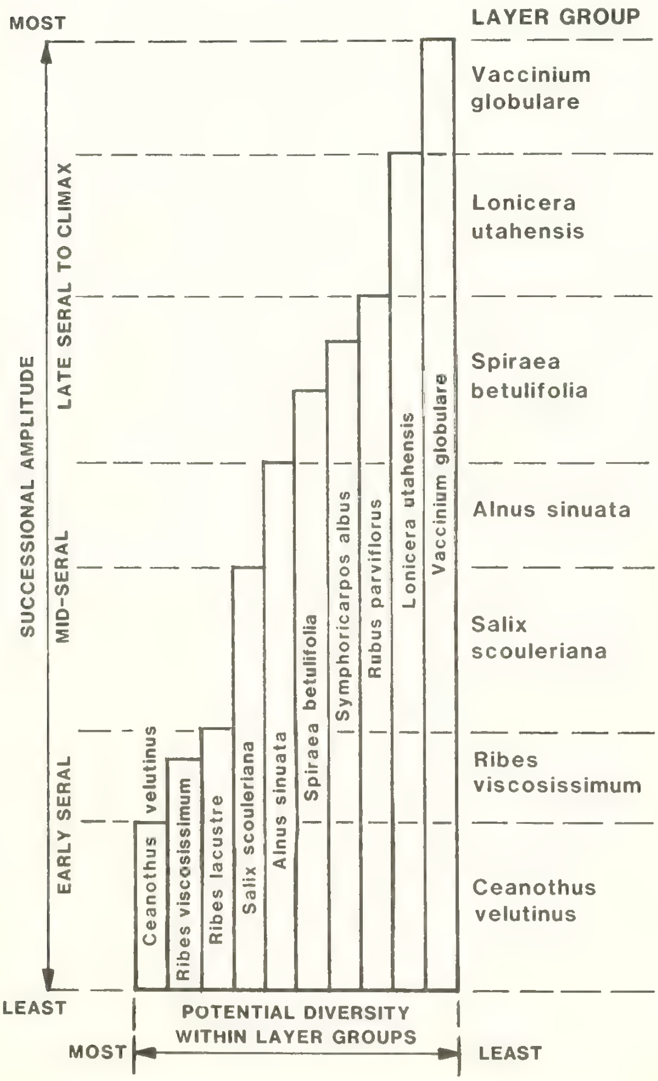


Figure 9—Relative successional amplitudes of major shrub species in ABGR/VAGL h.t.

Among the 85 shrub layers sampled, there are seven successional indicator species and three alternates. The alternate species occur in only part of the habitat type and are grouped with more widespread primary indicators having similar successional strategies and amplitudes. For instance, *Ribes lacustre* was grouped with *R. viscosissimum* because of similar seed storage capabilities and germination responses to scarification; *Symphoricarpos albus* and *Rubus parviflorus* were grouped with *Spiraea betulifolia* because of similar rhizomatous growth capabilities in late seral communities. A few other taxa, *Pachistima*, *Rosa*, and *Shepherdia*, were common throughout ABGR/VAGL but were only occasionally well represented and so were not used as indicator species (appendix B).

From the relative amplitudes (fig. 9), a succession classification diagram for shrub layers is easily constructed (fig. 10). The classification consists of seven shrub layer groups and 28 layer types (fig. 10). Of the 28 possible layer types, 23 occur in the present data set. The remaining five layer types may be found with more reconnaissance, may appear only after uncommon disturbances (or disturbance combinations), or may be rare under any circumstance.

The classification diagram (fig. 10) is, in turn, easily converted to a systematic key for field use (table 7). Indicator species (of layer groups) appearing early in the key have the least successional amplitude (greatest vulnerability) and so have greater indicator value than species with more amplitude, which appear progressively later in the key. This same ranking of indicator value is used to select the dominant indicator for layer types when several species codominate the site. Alternate indicator species (fig. 9) appear with their appropriate primary indicator throughout the key (table 7).

Average and range of years since disturbance of sampled layer types appear in appendix B. The low extreme of each range is meaningless because any layer type could have been recently disturbed; in these cases only disturbance intensity would vary between layer types. The upper yearly extremes and averages, which may reflect progression through several layer types, show a gradual though sporadic increase from left to right into successionally older shrub layers. This general progression of both years and layer types demonstrates that both entities delineate time, though in different ways.

Climax | Layer Group | Most

TIME (Successional Age) ↑ Climax … Seral ↓

SUCCESSIONAL INDICATOR (Successional Amplitude) ↑ Most … Least ↓

							Layer Group
						VAGL -VAGL *n* = 13	*Vaccinium globulare*
					LOUT -LOUT *n* = 2	LOUT -VAGL *n* = 14	*Lonicera utahensis*
				SPBE -SPBE *n* = 4	SPBE -LOUT *n* = 1	SPBE -VAGL *n* = 5	*Spiraea betulifolia*
			ALSI -ALSI	ALSI -SPBE *n* = 1	ALSI -LOUT	ALSI -VAGL *n* = 1	*Alnus sinuata*
		SASC -SASC *n* = 3	SASC -ALSI *n* = 2	SASC -SPBE *n* = 4	SASC -LOUT *n* = 1	SASC -VAGL *n* = 8	*Salix scouleriana*
	RIVI -RIVI *n* = 3	RIVI -SASC *n* = 1	RIVI -ALSI *n* = 2	RIVI -SPBE	RIVI -LOUT *n* = 4	RIVI -VAGL *n* = 2	*Ribes viscosissimum*
CEVE -CEVE *n* = 6	CEVE -RIVI *n* = 1	CEVE -SASC *n* = 1	CEVE -ALSI	CEVE -SPBE *n* = 2	CEVE -LOUT	CEVE -VAGL *n* = 4	*Ceanothus velutinus*

Seral | Least

DOMINANT

Less ← (Structural Development) → More

Figure 10—Succession classification diagram of the shrub layer in the ABGR/VAGL h.t.

Table 7—Key to shrub layer groups and layer types, with ADP codes, in ABGR/VAGL h.t.

		ADP codes
1. *Ceanothus velutinus* well represented[1] (Choose first condition that fits)	CEVE Layer Group	107
1a. *Ceanothus* dominant	CEVE-CEVE Layer Type	107.107
1b. *Ribes* spp. dominant or codominant	CEVE-RIVI Layer Type	107.131
1c. *Salix scouleriana* dominant or codominant	CEVE-SASC Layer Type	107.137
1d. *Alnus sinuata* dominant or codominant	CEVE-ALSI Layer Type	107.104
1e. *Spiraea*, (incl. *Symphoricarpos albus*, or *Rubus parviflorus*) dominant or codominant	CEVE-SPBE Layer Type	107.142
1f. *Lonicera utahensis* dominant or codominant	CEVE-LOUT Layer Type	107.115
1g. *Vaccinium globulare* dominant or codominant	CEVE-VAGL Layer Type	107.146
1. *Ceanothus* poorly represented	2	
2. *Ribes viscosissimum* (incl. *R. lacustre*) well represented (Choose first condition that fits)	RIVI Layer Group	131
2a. *Ribes* spp. dominant	RIVI-RIVI Layer Type	131.131
2b. *Salix scouleriana* dominant or codominant	RIVI-SASC Layer Type	131.137
2c. *Alnus sinuata* dominant or codominant	RIVI-ALSI Layer Type	131.104
2d. *Spiraea* (incl. *Symphoricarpos albus* and *Rubus parviflorus*) dominant or codominant	RIVI-SPBE Layer Type	131.142
2e. *Lonicera utahensis* dominant or codominant	RIVI-LOUT Layer Type	131.115
2f. *Vaccinium globulare* dominant or codominant	RIVI-VAGL Layer Type	131.146
2. *Ribes* spp. poorly represented	3	
3. *Salix scouleriana* well represented (Choose first condition that fits)	SASC Layer Group	137
3a. *Salix* dominant	SASC-SASC Layer Type	137.137
3b. *Alnus sinuata* dominant or codominant	SASC-ALSI Layer Type	137.104
3c. *Spiraea* (incl. *Symphoricarpos albus* and *Rubus parviflorus*) dominant or codominant	SASC-SPBE Layer Type	137.142
3d. *Lonicera utahensis* dominant or codominant	SASC-LOUT Layer Type	137.115
3e. *Vaccinium globulare* dominant or codominant	SASC-VAGL Layer Type	137.146
3. *Salix* poorly represented	4	
4. *Alnus sinuata* well represented (Choose first condition that fits)	ALSI Layer Group	104
4a. *Alnus* dominant	ALSI-ALSI Layer Type	104.104
4b. *Spiraea* (incl. *Symphoricarpos albus* and *Rubus parviflorus*) dominant or codominant	ALSI-SPBE Layer Type	104.142
4c. *Lonicera utahensis* dominant or codominant	ALSI-LOUT Layer Type	104.115
4d. *Vaccinium globulare* dominant or codominant	ALSI-VAGL Layer Type	104.146
4. *Alnus* poorly represented	5	
5. *Spiraea betulifolia* (incl. *Symphoricarpos albus* and *Rubus parviflorus*) well represented	SPBE Layer Group	142
5a. *Spiraea* (incl. *Symphoricarpos albus* and *Rubus parviflorus*) dominant	SPBE-SPBE Layer Type	142.142
5b. *Lonicera utahensis* dominant or codominant	SPBE-LOUT Layer Type	142.115
5c. *Vaccinium globulare* dominant or codominant	SPBE-VAGL Layer Type	142.146
5. *Spiraea*, *Symphoricarpos albus*, and *Rubus* poorly represented	6	
6. *Lonicera utahensis* well represented (Choose first condition that fits)	LOUT Layer Group	115
6a. *Lonicera* dominant	LOUT-LOUT Layer Type	115.115
6b. *Vaccinium globulare* dominant or codominant	LOUT-VAGL Layer Type	115.146
6. *Lonicera* poorly represented	7	
7. *Vaccinium globulare* well represented	VAGL Layer Group	146
7a. *Vaccinium* dominant	VAGL-VAGL Layer Type	146.146
7. *Vaccinium* poorly represented	depauperate or unclassified shrub layer.	

[1]"Well represented" means canopy coverage ≥5 percent. "Dominant" refers to greatest canopy coverage regardless of height, "codominant" refers to nearly equal canopy coverage. When keying to layer type, choose first condition that fits.

CEANOTHUS VELUTINUS LAYER GROUP (CEVE L.G.)

Ceanothus velutinus is a shade-intolerant nonrhizomatous shrub with values for big-game browse, songbird habitat (Thomas 1979), and nitrogen fixation (Youngberg and Wollum 1976). It is often the first shrub to dominate following wildfire or clearcutting and broadcast burning. *Ceanothus* declines substantially in the shade of other vegetation. It is known for its ability to store viable seed in the soil and duff for at least 200 to 300 years and to germinate readily following a heat treatment (Reed 1974). Kramer (1984) found viable *Ceanothus* seed buried in 75 percent of the ABGR/VAGL sites that he sampled. In ABGR/VAGL, *Ceanothus* can attain heights of 5 to 6 feet (1.5 to 1.8 m) in about 14 years. These heights contrast sharply with less productive habitat types such as Douglas-fir/pinegrass where *Ceanothus* reaches only about 3 feet (0.9 m) (Steele and Geier-Hayes 1984).

The CEVE l.g. represents some of the most common early seral shrub layers in ABGR/VAGL. Of the seven CEVE layer types that may occur in ABGR/VAGL (fig. 10), only the CEVE-ALSI and CEVE-LOUT layer types were not found. CEVE-ALSI is probably quite rare because *Ceanothus* and *Alnus* seldom occur on the same site; *Lonicera*-dominated layer types tend to be uncommon.

The CEVE l.g. is typically a response to various intensities or frequencies of burning, but can also appear following scarification (fig. 11). It is perhaps the easiest shrub layer group to achieve following disturbance and responds dependably to burning on slopes with good cold air drainage. CEVE layer types are not apt to appear in areas that accumulate cold air and that act as frost pockets. Such conditions may also be too cold for *Pinus ponderosa* pine to grow properly and better suited for *P. contorta* and *Picea engelmannii.* The CEVE l.g. rarely appears on sites where *Alnus sinuata* can dominate. Apparently the *Ceanothus* seed does not store successfully on these wetter sites (Kramer 1984). In these wetter situations, *Picea* is apt to be more successful than *Pinus ponderosa.* With proper site treatment, the CEVE l.g. is a practical cover for protecting disturbed sites. A dense canopy of *Ceanothus* (generated by a high-intensity

Figure 11—A *Ceanothus velutinus - Ceanothus velutinus* shrub layer type near Price Valley Guard Station. This 6-year-old seedtree cut was heavily scarified but not burned. A patchy cover of *Ceanothus* resulted from the scarification and now dominates the site. *Ribes* is scarce; apparently there was little seed in the soil. Adjacent unlogged sites suggest that the predisturbance shrub layer was a dense climax VAGL-VAGL layer type. Now *Vaccinium* is only present in trace amounts.

prescribed burn) will deter livestock and erosion; a light canopy (generated by a low-intensity burn) can provide shelter for *Pseudotsuga* seedlings. Following clearcutting and burning in the Oregon Cascade Range, *Ceanothus* enhanced stockability and growth of naturally established coastal *Pseudotsuga* seedlings for about the first 7 years, after which competition began to outweigh the benefits (Youngberg and others 1979). The improved performance of *Pseudotsuga* was attributed to higher nitrogen levels, amelioration of microenvironment, or a combination of these effects. In another study in the Oregon Cascade Range (Petersen and Newton 1985), planted coastal *Pseudotsuga* benefited from an herbicide treatment of dense *Ceanothus* and other vegetation 5 years after planting. Plantations that received the same treatment at 10 years of age benefited substantially less. Reduction of *Ceanothus* canopy by cutting the stems at year 10 had no effect on *Pseudotsuga* height growth.

RIBES VISCOSISSIMUM LAYER GROUP (RIVI L.G.)

Ribes viscosissimum and *R. lacustre* are characteristically early seral nonrhizomatous shrubs, often the first to dominate well-scarified sites that lack rhizomatous shrubs. Having a low tolerance for shade, these *Ribes* begin declining shortly after a canopy taller than their own develops. The *Ribes*, however, seem to maintain themselves longer toward climax than does *Ceanothus* (appendix B) and so are considered slightly less vulnerable to succession (fig. 9). Like *Ceanothus*, numerous seed of *Ribes* remain viable in the soil and duff long after the parent shrubs have disappeared. Kramer (1984) found *Ribes* seed buried in 69 percent of the ABGR/VAGL sites that he sampled. Although *R. viscosissimum* may occur throughout ABGR/VAGL, *R. lacustre* is more restricted to wetter sites that can also support *Alnus* and *Picea*.

The classification diagram (fig. 10) shows six possible layer types in the RIVI l.g. Only one, RIVI-SPBE, was not found, but it is apt to appear following scarification of shrub layers in which *Spiraea* is well represented. Although *Lonicera*-dominated shrub layers are uncommon, four examples of RIVI-LOUT were found in clearcuts. In all four cases, apparently a LOUT-VAGL layer type had received shallow scarification so as to remove the *Vaccinium*, but the more deeply rooted *Lonicera* had survived the bulldozer blade and resprouted. The *Ribes* had germinated from buried seed following the scarification.

In general, the RIVI l.g. originates from various types of scarification without burning (fig. 12). It is most common in scarified portions of past pile-and-burn operations and rarely occurs on intensely burned areas. The RIVI l.g., and especially the RIVI-RIVI layer type, generate the least competition for tree seedlings of any early to midseral shrub layer in ABGR/VAGL. The maximum height of *Ribes* is about 3 feet (0.9 m), and although this height is attained within 5 years, the canopy is sparse and should not outcompete ponderosa pine seedlings.

SALIX SCOULERIANA LAYER GROUP (SASC L.G.)

Salix scouleriana is a nonrhizomatous shrub that has high value for big-game browse (appendix B). It can also provide nesting and feeding habitat for small birds and site protection for conifer seedlings. Though only slightly tolerant of shade, its tall growth habit—up to 24 feet (7.3 m) in ABGR/VAGL—and sprouting ability enable this *Salix* to persist in small openings on well-timbered sites. Its light, windblown seeds are dispersed in late spring, have a short-lived viability, and require moist mineral soil for germination (Brinkman 1974).

The SASC l.g. represents a midseral stage of shrub layer succession and consists of five layer types in ABGR/VAGL (fig. 10). All of these have been sampled, with SASC-VAGL being the most common.

In the past, this layer group resulted from stand-destroying wildfires, but today broadcast burn operations do not always burn hot enough to create an adequate seedbed for *Salix*. Such treatments usually generate a CEVE layer type which lacks *Salix* and bypasses the SASC l.g. during succession. SASC layer types have developed following mechanical scarification in clearcuts, especially where exposed soil was mounded so as to trap water behind the mounds, thus creating well-watered seedbeds of mineral soil. Most stands sampled in this layer group had received machine scarification from pile-and-burn or contour terrace operations 11 to 24 years ago (fig. 13) or experienced a severe wildfire over 50 years ago.

The SASC l.g. may enhance *Pseudotsuga* or *Picea* establishment by protecting the site and providing partial shade, but it is a formidable competitor of *Pinus ponderosa*. Having a low tolerance for shade, the pine must outgrow *Salix* in order to survive. This is barely possible when *Salix* seedlings are involved because planted pine and *Salix* seedlings have similar growth rates for about the first 6 years. But when the *Salix* arises from stump sprouts that can outgrow the pine in the first year, the pine has little chance for survival. Even when contour terraces are installed next to *Salix* stumps, the pine is shaded out by the height and lateral spread of the *Salix*. In full sunlight, *Salix* stumps can produce tall rounded shrubs up to 16 feet (4.9 m) in diameter. Consequently, uncut stands with a *Salix* density of at least one every 16 feet (4.9 m) may lack potential growing space for pine seedlings following clearcutting. Such sites may require special mechanical or chemical treatment following clearcutting where pine plantations are a management objective.

ALNUS SINUATA LAYER GROUP (ALSI L.G.)

Alnus sinuata is a nonrhizomatous seral shrub that has little forage value but provides habitat for small birds and fixes nitrogen in the soil (Mitchell 1968). Though only slightly shade tolerant, its widely spreading growth habit enables it to persist on timbered sites by intercepting

Figure 12—A *Ribes viscosissimum - Ribes viscosissimum* shrub layer type northeast of Bear, ID. This site was clearcut and scarified without burning 11 years ago. It was planted to ponderosa pine, Douglas-fir, and western larch the following year. Both *Ribes viscosissimum* and *R. lacustre* responded to the scarification and now codominate the shrub layer. This shrub layer type creates the least competition for tree seedlings of any shrub layer in ABGR/VAGL h.t.

Figure 13—A *Salix scouleriana - Vaccinium globulare* shrub layer type near Bessie Gulch northeast of Bear, ID. This site was clearcut and lightly scarified by a dozer-pile and burn treatment 11 years ago. Ponderosa pine and Douglas-fir were planted the following year; lodgepole pine established naturally. *Salix*, mainly from seedlings, is established where the soil had been exposed. *Vaccinium* survived the shallow scarification treatment and continues to have the greatest shrub coverage. No other shrub species are well represented. As the tree layer develops, this shrub layer will likely progress directly to a VAGL-VAGL layer type.

sunlight that passes through the tree canopy. *Alnus* has a light, wind-disseminated seed that requires moist mineral soil for germination. Although it generally forms thickets from seed, the *Alnus* can also sprout from stumps and reach a maximum height of 10 to 13 feet (3.0 to 4.0 m). High coverages of *Alnus* occur in only the wetter portions of ABGR/VAGL and indicate sites suitable for *Picea engelmannii* and generally unsuitable for *Ceanothus* and possibly *Pinus ponderosa*.

The ALSI l.g. represents midseral shrub layers in ABGR/VAGL and consists of four layer types, two of which were found (fig. 10). It is not widespread in ABGR/VAGL but can appear unexpectedly following clearcutting and scarification. The rapid growth rate of *Alnus* may preclude success of ponderosa pine seedlings, making it imperative to recognize potential *Alnus* sites before planting. The presence of *Alnus* is the best indicator of such conditions, but the presence of *Actaea, Trautvetteria, Circaea*, or a high density of *Picea* generally indicate sites wet enough for *Alnus* invasion.

SPIRAEA BETULIFOLIA LAYER GROUP (SPBE L.G.)

Spiraea betulifolia is a moderately shade-tolerant rhizomatous shrub with root development well down into the soil profile. Mechanical scarification and stripping seldom remove completely the *Spiraea* root system, which will resprout within the next growing season. *Spiraea* also provides moderate amounts of forage for mule deer in summer and fall (Kufeld and others 1973).

Symphoricarpos albus and *Rubus parviflorus* may be slightly more shade tolerant than *Spiraea* (fig. 9), but are treated as successional equivalents in ABGR/VAGL because neither species appears frequently enough to justify a separate layer group. Like *Spiraea*, these two species also develop extensive rhizomes that usually resprout following scarification of the site. They also provide moderate forage for deer and elk as well as food for black bear (appendix B).

The SPBE l.g. occurs mainly in drier portions of ABGR/VAGL. It is treated here as a late seral stage of shrub layer succession but may represent a near-climax stage (especially SPBE-VAGL) when occurring on sites transitional to the grand fir/white spirea habitat type. The SPBE l.g. consists of three layer types, all of which were sampled (fig. 10). The SPBE-SPBE and SPBE-LOUT layer types in all sample plots resulted from clearcutting and thorough scarification, usually a pile-and-burn operation, 4 to 9 years ago (fig. 14). Although *Ribes* was present on all sites, the amount of buried *Ribes* seed was apparently inadequate to produce the *Ribes* layer types typical of this site treatment. The *Spiraea* and *Lonicera* likely resprouted from residual roots that survived the scarification. The SPBE-VAGL layer type occurred mainly beneath a tree canopy and was the result of uninterrupted succession following the last wildfire 30 to 80 years ago.

LONICERA UTAHENSIS LAYER GROUP (LOUT L.G.)

Lonicera utahensis is a shade-tolerant, nonrhizomatous shrub that is able to persist beneath a near-climax tree canopy. As the shrub layer approaches climax, *Lonicera* slowly loses its foothold because of its inability to increase vegetatively. Upon disturbance, the deeply rooted *Lonicera* often survives scarification and broadcast burns. In full sun, it develops a well-rounded canopy about 3 feet (0.9 m) tall and has moderate to high forage value for deer, elk, and black bear (appendix B). The fleshy coated seeds are probably dispersed by birds, rodents, and bears, but natural seedbed conditions are unknown. Kramer (1984) sampled buried seed composition of 16 stands in ABGR/VAGL but found no viable seeds of *Lonicera*, yet all of those stands contained the living shrub. Thus it appears that *Lonicera* seed does not long remain viable in soil or duff.

The LOUT l.g. consists of two layer types and indicates a near-climax shrub layer (fig. 10). Conceivably it could result from light disturbance beneath a partial tree canopy as in the case of a shelterwood system for *Pseudotsuga* or *Abies*. It is known to occur following clearcutting with scarification (LOUT-LOUT, fig. 15) or clearcutting with no site treatment (LOUT-VAGL). In these cases, the *Lonicera* appears to have been established prior to clearcutting and simply resprouted from root crowns, its vigor renewed by the increased sunlight. In most cases, however, the LOUT l.g. was found beneath mature to old-growth timber that experienced a surface fire about 80 years ago. Of the two layer types in the LOUT l.g., only the LOUT-VAGL layer type is common (fig. 10). The LOUT-LOUT layer type is apparently rare.

VACCINIUM GLOBULARE LAYER GROUP (VAGL L.G.)

Vaccinium globulare is a shade-tolerant rhizomatous shrub that has high food value for deer, elk, and black bear (appendix B). It has a relatively shallow root system making it quite vulnerable to scarification and high-intensity burns. Low-intensity burns that do not destroy the *Vaccinium* rhizomes, can stimulate new shoots and berry production (Miller 1977). Reducing overstory shade without disturbing the *Vaccinium* may also increase berry production (Minore 1984). The seeds, which are dispersed by birds and mammals, may remain stored in the soil and litter. They will germinate in partial shade on moist mineral soil.

The VAGL l.g., which consists only of VAGL-VAGL, occurs mainly in old-growth stands but can also occur where the tree layer has been removed without killing the *Vaccinium* or allowing other species to establish. If the VAGL l.g. is disturbed, the resulting layer type will depend on the kind and intensity of disturbance, the amount of sunlight available, the species and quantities of available windblown seed and seed stored in the soil and duff, and the composition of remnant seral shrubs in the stand.

Figure 14—A *Spiraea betulifolia - Lonicera utahensis* shrub layer type northwest of Tamarack, ID. *Spiraea* and *Lonicera* both survived the clearcut and scarification treatment that occurred here 9 years ago. They are the only shrubs well represented; together they codominate the site. Being a late seral stage, this shrub layer type will persist long after the planted pines have formed a mature canopy.

Figure 15—A *Lonicera utahensis - Lonicera utahensis* shrub layer type in the Squaw Creek drainage northwest of Smith's Ferry, ID. This site was clearcut 15 years ago. Contour strips were scraped across the slope in order to plant lodgepole pine. The *Lonicera*, which existed prior to logging, has increased its canopy in response to the increased sunlight and now dominates the shrub layer. *Vaccinium*, the only other shrub species well represented, was reduced somewhat by the logging disturbance.

MANAGEMENT IMPLICATIONS

The previous sections describe some layer groups that can be achieved through prescribed site treatments. Actual layer types within the group can often be projected on a stand-by-stand basis from species composition. When considering alternative shrub layers resulting from different site treatments, land managers may wish to assess relative forage value of layer types for big game and livestock. Such values can be estimated from relative palatability ratings of plant species for elk (Kufeld 1973), deer (Kufeld and others 1973), cattle and sheep (USDA-FS n.d.), and black bear (Beecham 1981). The scale in these studies of 1 to 3 was expanded to 2 to 6 so as to emphasize the differences in palatability values. The relative palatability value for each plant species is listed in appendix B. This value was multiplied by the percentage constancy and average canopy cover (appendix B) for that species in a given layer type. This step was repeated for all species in the layer type. The sum of all such products within a layer type resulted in a forage index value for that particular layer type. The index values were then reduced to classes in order to simplify forage value assessments and to eliminate the impression of high precision between values (table 8).

These index classes reflect forage potential on a relative basis but do not necessarily reflect actual use, which is affected by juxtaposition of the surrounding vegetational types. Some index values may be biased by inconsistent proportions of canopy cover to shrub volume. Likewise actual palatability within a species can vary with plant vigor; however, other sources of variation common to this type of comparison have been reduced. For instance, the possibility of ecotypes within a plant species is reduced by restricting the data to one habitat type. Individual animals may have slightly different forage preferences, but all possible layer types can be made available to the same group of animals. Plant species palatabilities are listed by season to accommodate seasonal forage preferences. In spite of the shortcomings inherent with these kinds of comparisons, the forage index classes can provide general

Table 8—Relative index classes to big-game and livestock forage preferences by shrub layer type in ABGR/VAGL h.t.[1]

Layer group layer type	No. of stands	Deer SU[2]	Deer W	Elk SU	Elk W	Cattle SU	Sheep SU	Black bear SP	Black bear SU	Black bear F
Ceanothus velutinus										
CEVE-CEVE	6	[3]5	3	5	4	2	2	0	1	1
CEVE-RIVI	1	3	3	4	3	2	2	0	1	1
CEVE-SASC	1	4	3	4	3	1	2	0	0	0
CEVE-SPBE	2	4	3	4	4	2	3	0	1	1
CEVE-VAGL	4	5	4	6	4	2	4	1	3	2
Ribes viscosissimum										
RIVI-RIVI	3	3	3	4	4	1	3	1	3	2
RIVI-SASC	1	3	3	3	2	1	2	1	2	1
RIVI-ALSI	2	4	5	6	5	3	4	1	3	2
RIVI-LOUT	4	3	3	4	4	1	2	1	3	2
RIVI-VAGL	2	4	3	5	3	2	3	1	4	3
Salix scouleriana										
SASC-SASC	3	4	4	4	4	1	3	0	1	1
SASC-ALSI	2	4	3	4	4	2	4	1	2	1
SASC-SPBE	4	4	3	5	3	2	3	1	2	1
SASC-LOUT	1	3	3	5	3	2	2	1	3	2
SASC-VAGL	8	6	5	6	4	2	4	2	5	3
Alnus sinuata										
ALSI-SPBE	1	2	2	3	2	1	2	1	2	1
ALSI-VAGL	1	6	5	7	3	3	4	2	6	4
Spiraea betulifolia										
SPBE-SPBE	4	1	1	1	1	1	1	0	0	0
SPBE-LOUT	1	1	1	2	1	1	1	0	1	1
SPBE-VAGL	5	5	3	5	3	2	3	1	4	3
Lonicera utahensis										
LOUT-LOUT	2	3	3	4	3	2	2	1	3	2
LOUT-VAGL	14	5	4	5	2	2	3	2	5	3
Vaccinium globulare										
VAGL-VAGL	13	3	2	3	1	1	2	1	3	2

[1]Based on palatability ratings by Kufeld (1973), Kufeld and others (1973), USDA-FS (n.d.), and Beecham (1981).

[2]SP = spring (March, April, May); SU = summer (June, July, August); F = fall (September, October, November); W = winter (December, January, February).

[3]Code to index classes: 0 = 0-50; 1 = 51-150; 2 = 151-250; 3 = 251-350; 4 = 351-450; 5 = 451-550; 6 = 551-650; 7 = 651-750.

guidelines to relative browse potential for specific wildlife and range objectives as well as multifunctional planning. Range and wildlife managers who may have better species palatability ratings for a local area can easily recalculate the forage indexes from appendix B, reduce the indexes to index classes (table 8), and apply the results to their area.

Forage index classes (table 8) vary according to kinds and amounts of plant species comprising the layer type. Because early seral layer types may contain a wider variety of plants than later stages, a greater data base is often needed to reflect actual modal conditions and forage indexes in these early stages. When the same layer type occurs in different habitat types or phases, variability of the index may increase with potential of the site and more samples may be needed for the more productive site. The index value, however, is most affected by coverages of the most palatable species and does not necessarily increase with site productivity although this often is the case. Ranking of species' nutritional value between habitat types could add refinement to the index values. Such considerations are needed when comparing relative significance of forage index classes.

Deer—Of the shrub layer types sampled in ABGR/VAGL, the highest forage index for summer deer herds occurred in the SASC-VAGL and ALSI-VAGL layer types (table 8). This was due mainly to the high coverage of *Vaccinium* (highly palatable) in these stands. Layer types having the second highest forage index include CEVE-CEVE, CEVE-VAGL, SPBE-VAGL, and LOUT-VAGL. Thus it appears that most *Vaccinium*-dominated shrub layers are important for summer mule deer in ABGR/VAGL. All of the above layer types, except CEVE-CEVE, can be achieved by simply reducing the tree canopy where *Vaccinium* dominates the undergrowth. The actual layer type that results will depend on total shrub composition in the stand. In contrast, scarification, which usually produces the RIVI l.g. in clearcut areas, will eliminate much of the shallow-rooted *Vaccinium* and the high summer forage value for deer (table 8). In clearcuts, burning to produce a CEVE-CEVE layer type, rather than scarification, may be a more desirable method of site preparation in key mule deer areas.

In winter, forage values are low to moderate throughout ABGR/VAGL succession. The SASC-VAGL and ALSI-VAGL layer types still have the highest value (table 8), but snow depths likely preclude much foraging on these sites. The RIVI-ALSI layer type also ranked high due to the higher winter forage value of *Ribes* (appendix B).

Elk—The highest forage indexes for summer elk include the same layer types as for deer and for similar reasons. The ALSI-VAGL layer type ranked highest, followed by CEVE-VAGL, RIVI-ALSI, and SASC-VAGL (table 8). These layer types have a forage index of 6 or above for summer elk. Forage values for elk may be slightly greater than for deer in ABGR/VAGL, especially when grazing values of the herb layer (see herb layer section) are also considered.

Forage indexes for winter elk herds are low to moderate. The highest values occur in the CEVE, RIVI, and SASC l.g.'s (table 8).

Cattle—Shrub forage values for cattle are low throughout ABGR/VAGL succession. These low indexes reflect the generally low palatability of most major shrub species in ABGR/VAGL. But even when grazing values of the herbaceous layer are included, total forage value for cattle is generally less in ABGR/VAGL than for deer and elk.

Sheep—Forage values for sheep range from low to moderate. The highest values occurred in the CEVE-VAGL, RIVI-ALSI, SASC-ALSI, SASC-VAGL, and ALSI-VAGL layer types. All of these layer types, however, also ranked as high or higher for either deer or elk (table 8).

Black Bear—In spring, shrub forage values for black bear are low throughout ABGR/VAGL succession but increase substantially with development of various fruit crops. In summer, the ALSI-VAGL layer type followed by SASC-VAGL and LOUT-VAGL (table 8) have the highest index classes. In all cases, these high indexes hinge on the dominant coverage of *Vaccinium*, the major berry producer. These three layer types were also among those ranking highest for deer and elk, which emphasizes the often high value of midseral to late seral shrub layer conditions for big game in general. In the fall, most forage indexes for bear decline by at least one class, but the ALSI-VAGL layer type still has the highest value. Fall fruiting shrubs, particularly *Sorbus*, contribute to the higher fall indexes in some of these layer types.

Planted Tree Seedlings and Shrub Competition—Potential shrub competition with tree seedlings is a function of existing vegetation, seed availability, site treatment, and habitat type or phase. The habitat type or phase classifies the environment, which in turn determines which species can occur on the site and the magnitude of their potential roles. Table 9 lists the shrub species most likely to occur in ABGR/VAGL and their successional role in this habitat type. Predicting what species might occur

Table 9—Successional roles of shrub species in ABGR/VAGL h.t.

ADP No.	Species	Abbreviation	Role[1]
102	*Acer glabrum*	ACGL	c
104	*Alnus sinuata*	ALSI	(S)
105	*Amelanchier alnifolia*	AMAL	s
150	*Artemisia tridentata*	ARTR	a
203	*Berberis repens*	BERE	(s)
107	*Ceanothus velutinus*	CEVE	(S)
108	*Chrysothamnus nauseosus*	CHNA	a
109	*Cornus stolonifera*	COST	a
111	*Holodiscus discolor*	HODI	a
114	*Lonicera involucrata*	LOIN	a
115	*Lonicera utahensis*	LOUT	S
118	*Pachistima myrsinites*	PAMY	(c)
122	*Physocarpus malvaceus*	PHMA	(c)
123	*Prunus emarginata*	PREM	(s)
128	*Ribes cereum*	RICE	a
158	*Ribes hudsonianum*	RIHU	a
130	*Ribes lacustre*	RILA	(S)
131	*Ribes viscosissimum*	RIVI	S
133	*Rosa gymnocarpa*	ROGY	s
161	*Rosa nutkana*	RONU	(s)
136	*Rubus parviflorus*	RUPA	(S)
137	*Salix scouleriana*	SASC	S
164	*Sambucus cerulea*	SACE	(s)
138	*Sambucus racemosa*	SARA	s
139	*Shepherdia canadensis*	SHCA	s
140	*Sorbus scopulina*	SOSC	s
142	*Spiraea betulifolia*	SPBE	S
143	*Symphoricarpos albus*	SYAL	(S)
163	*Symphoricarpos oreophilus*	SYOR	(s)
146	*Vaccinium globulare*	VAGL	C
148	*Vaccinium scoparium*	VASC	a

[1]S = major seral; s = minor seral; C = major climax; c = minor climax; a = accidental; ( ) = occurs in only part of the habitat type, usually the wetter portion or the warmer-drier portion.

or dominate by simply inspecting a site prior to disturbance is not always possible. Old-growth stands may contain a multitude of early seral species in the form of buried seed (Kramer 1984); other species establish by windblown seed. Table 10 shows which shrubs in ABGR/VAGL store seed in the soil and important methods of seed dissemination, vegetative increase, and germination response to site treatment. For instance, if *Ribes* occurs in the stand, the existing *Ribes* canopy may increase somewhat in a clearcut with no site preparation (table 10). If the clearcut is scarified, existing plants will increase their canopies due to the clearcut, but the scarification will also reduce total canopy cover and cause *Ribes* seed to germinate in proportion to the scarification. Potential shrub competition for a given site is best estimated by noting kinds and amounts of existing shrubs on that site, the other species that may occur (table 9), and reactions of all species to the site treatment planned (table 10). In contrast, generalized descriptions of site treatment and potential shrub responses tend to represent an average stand condition. Such predictions can be misleading for site-specific management because few stands would fit the average, thus many plantations could be lost to unexpected competition.

Duration of the competition depends on height-age interactions of tree seedlings with the shrubs and shrub density. As noted (table 10), existing and potential shrub densities can be regulated by the kind and intensity of site treatment (guarding against the possibility of increasing one undesirable shrub species while reducing another). Height-age interactions in ABGR/VAGL are generalized in figure 16. If free from suppression, properly planted *Pinus ponderosa* can outgrow most shrubs germinating from seed at the time of planting. Only *Ribes* will substantially overtop the pine within the first 6 years (fig. 16), but a *Ribes* canopy is usually sparse and does not strongly suppress pine growth. The *Ribes* growth curve (fig. 16) is

Table 10—Responses of major shrub species to various disturbances

Species	Seed transport, reproduction methods	Maximum heights	CC, NP	SC, MS	CC, MS	CC, BB	WF
			Type of disturbance				
		Feet					
VAGL	Birds, mammals; stored in soil (23% viable).[1] Germinates in partial shade on moist mineral soil. Increases by shallow rhizomes.	2½ - 3½	v	V-s	v	v	v
LOUT	Birds, mammals; not stored in soil. Root crowns resprout following fire or logging.	2½ - 3½	v	v	v	v	v
RUPA	Birds, mammals; stored in soil (14% viable). Increases by rhizomes.	2 - 3	V	V	V	V	V
SYAL	Birds, mammals; not stored in soil. Increases by rhizomes.	1 - 1½	V	v	V	V	V
SPBE	No obvious transport; not stored in soil. Increases by rhizomes.	1 - 2	V	v	V	V	V
ALSI	Wind; not stored in soil. Germinates on moist soil in full sun. Stumps resprout.	10 - 13	v	v	v-S	v-s	v-s
SASC	Wind; not stored in soil. Germinates on moist mineral soil in full sun. Stumps resprout.	20 - 24	V	v	V-s	V-s	V-s
RIVI	Birds, mammals; stored in soil (96% viable). Germinates on mineral soil in full sun.	2½ - 3½	v	v-s	v-S	s	s
CEVE	No obvious transport; stored in soil (91% viable). Germinates mainly from burning and partially from scarification in full sun.	5 - 6	v	v	v-s	S	S

DISTURBANCE CODES:
CC, NP = Clearcut, no site preparation
SC, MS = Shelterwood cut, mechanical scarification
CC, MS = Clearcut, mechanical scarification
CC, BB = Clearcut, broadcast burned
WF = Stand-destroying wildfire

RESPONSE CODES:
V = Major vegetative response (coverage increases from existing plants and vigorous sprouting following tree removal but is offset by treatment intensity).
v = Minor vegetative response (coverage increases either from just the existing plants following tree removal or from existing plants and nonvigorous sprouting but is offset by treatment intensity).
S = Major response from seed (coverage increase depends on amount of viable seed available and is enhanced by treatment intensity).
s = Minor response from seed (same criteria as for S).

[1]Stored seed viabilities are from Kramer (1984).

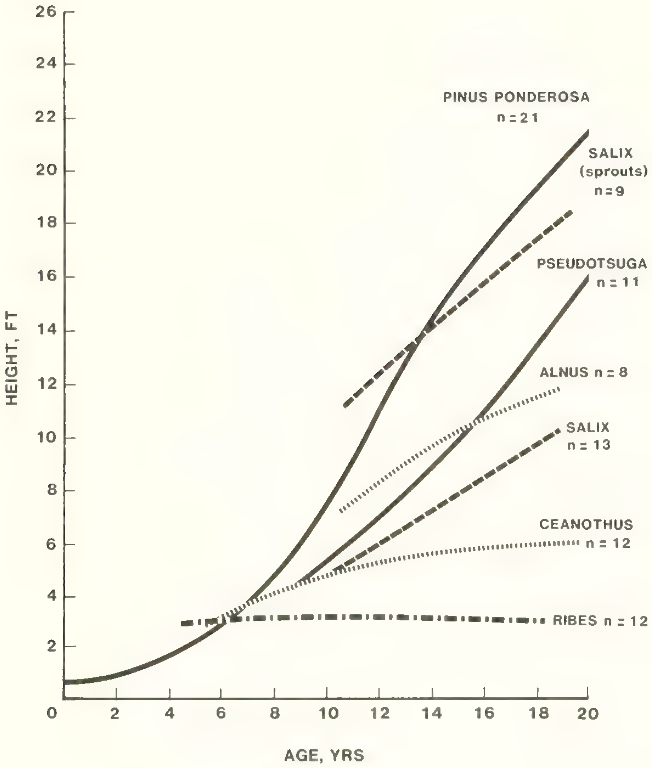


Figure 16—Height-age relationships of free-growing tree seedlings and important shrubs in ABGR/VAGL h.t.

based on *R. viscosissimum; R. lacustre* has a similar curve but is slightly shorter. Seedlings of *Alnus sinuata* might outgrow planted pine, but the entire *Alnus* growth curve was not shown in figure 16 due to insufficient data. Whenever pines are planted after the first growing season following disturbance, shrub seedlings such as *Ceanothus, Salix,* or *Alnus* may outcompete the pines (fig. 17).

Sprouting ability varies among species and also with size and vigor of the individual. Of the major shrubs in ABGR/VAGL, *Salix* has the greatest sprouting ability. Figure 16 suggests that it would take ponderosa pine about 13 years to overtop *Salix* sprouts. If the site in question has a high density of *Salix* and pine is to be planted, deep scarification to remove the *Salix* stumps may be needed to reduce competition. The scarification will encourage *Ribes* and *Salix* from seed (table 10), but properly planted pines can outgrow these seedlings (fig. 16). If the site in question occurs at the moist extreme of ABGR/VAGL, *A. sinuata* may also appear following scarification (tables 9, 10). The growth curve of *Alnus* sprouts in relation to planted pines in ABGR/VAGL is not known; but *Alnus* sprouts, like *Salix* sprouts (fig. 16), will surely outcompete the pine. When severe competition from sprouting *Salix* or *Alnus* is inevitable, either mechanical or chemical treatment will be needed where pine plantations are a management objective. An alternative is to manage for the more shade-tolerant *Pseudotsuga* or *Picea.*

Figure 17—A ponderosa pine plantation lost to shrub competition. This area was clearcut and broadcast burned 18 years ago. *Ceanothus* began developing a shrub layer in response to the burning. After three growing seasons, the site was planted to ponderosa pine. The planted pines could not outgrow the *Ceanothus*, which had a 3-year lead, and are now badly suppressed beneath the dense shrub layer.

The above paragraphs show how components of tables 9 and 10 and figure 16 can be assembled to meet stand-specific conditions. Considerations for each stand may differ but should include:

1. The desired tree species, its shade tolerance and growth rate;
2. The kind and intensity of site treatment needed to favor the desired tree species and reduce existing competition;
3. Existing shrub species and their potential for reacting to the proposed timber harvest and site treatment;
4. Potential reactions of buried seed and windblown seed to the site treatment selected; and
5. Duration of the potential competition in terms of height-age interactions of shrub species and tree seedlings.

This set of interacting variables may seem complex at first but, once learned, provides an ecological basis for prescribed treatments on a stand-specific basis. Until more specific information is available, these variables can be extrapolated to similar habitat types by adjusting for changes in species composition and growth potential. More productive habitat types may support additional shrub species whose successional roles and reproductive strategies will need to be considered. Less productive habitat types may support fewer species (although new species may appear) and may have less complex successions.

Natural Tree Establishment—Naturally established tree seedlings were recorded by species, silvicultural treatment, and microsite conditions. A seedling was defined as a tree less than 4.5 feet (1.4 m) tall and 3 years old or older, but younger than the disturbance. Although a separate study (Geier-Hayes 1985), the natural tree establishment study was conducted concurrently with succession studies of the ABGR/VAGL and grand fir/mountain maple (ABGR/ACGL) h.t.'s.

A total of 242 natural seedlings were recorded in ABGR/VAGL. Of these, 60 percent were *Abies grandis*, 14 percent were *Pseudotsuga*, and 13 percent *Picea*. The average number of seedlings per acre and percentage of total for each species are shown in table 11. A regeneration efficiency (RE) value was computed for each seedling species in each microsite. An RE value of 1.00 indicates that the seedlings occurred on a particular microsite in proportion to the occurrence of the microsite. Values greater than 1.00 are designated very efficient (possibly beneficial), 0.75 to 0.99 moderately efficient (slightly beneficial), 0.25 to 0.74 slightly efficient (beneficial or detrimental), and less than 0.25 inefficient (detrimental). RE values were calculated for the microsite seedbed and canopy cover, if present. In order to strengthen the data base, RE values for canopy cover vegetation were calculated using data from the ABGR/VAGL and ABGR/ACGL h.t.'s. Even though ABGR/VAGL is somewhat cooler than ABGR/ACGL, other environmental conditions of these two habitat types are similar.

Although RE values may reflect a relationship between the microsite and tree seedling, several factors affect interpretation of these values. It was assumed that seedlings persist only in a favorable microsite: one that promotes germination **and** provides the resources for growth and development (Harper 1977). If a seed germinates in a favorable microsite and the microsite deteriorates, such as through rapid shrub development, the seedling should die. Some seedlings may have been recorded in unfavorable microsites such as a microsite which provided the stimulus for germination but cannot provide the resources for continued development. Therefore, some microsites identified as beneficial may in fact preclude development of a mature tree. In this respect, the microsite canopy cover is more influential than the seedbed through time, but the relationship between the microsite canopy cover and seedling was not always easy to determine. In some cases, the tree seedling and canopy cover may have benefited from the same microsite and simply established near one another coincidentally. In other cases, the tree seedling may have benefited from existing cover vegetation, which provided more favorable microsite conditions in terms of light, soil moisture and nutrients, humidity, temperature, and wind protection (Zavitkovski and Woodard 1970).

Table 11—Average number of natural seedlings per acre in ABGR/VAGL h.t.

Seedling species	Number of seedlings counted	Average seedlings per acre	Percentage of total sample
PICO	19	64	7.9
LAOC	1	3	.4
PIPO	13	44	5.4
PSME	33	111	13.6
PIEN	31	104	12.8
ABGR	145	489	60
Total	242	815	100

Figure 18—An example of a seedling microsite. The protection of a burned log, a canopy of *Ceanothus*, and mineral soil having a light litter cover contribute to a favorable microsite for these *Pseudotsuga* seedlings.

Some microsites having cover vegetation may favor one seedling species but not another (fig. 18). A heavy canopy cover may favor shade tolerant tree species but not shade intolerant species, or an allelopathic cover species may preclude establishment of some tree seedlings. Where a positive seedling-microsite relationship exists, the canopy cover species may be used to help establish natural regeneration, or to indicate favorable microsites. Where a negative relationship exists, canopy cover species may be used to indicate unfavorable microsites.

Table 12—Occurrence of natural seedlings (percent) by silvicultural method and percent overstory composition

Silvicultural method	Number of sites sampled[1]	Seedling occurrence, percent[2]					
		PICO	LAOC	PIPO	PSME	PIEN	ABGR
CLEARCUT	60	55	12	10	24	23	11
SEED-TREE CUT	8	28	68	75	43	34	10
Overstory, pct		**Seedling occurrence (percent) within seed-tree cuts**					
LAOC 3	1	—	52	—	—	—	—
LAOC 3, PIEN 15	1	100	39	—	13	95	69
PIPO 3	3	—	9	9	22	5	19
PIPO 1, ABGR 15	1	—	—	91	65	—	6
ABGR 15[3]	2	—	—	—	—	—	6
SHELTERWOOD CUT	5	—	—	13	3	38	9
Overstory, pct		**Seedling occurrence (percent) within shelterwood cuts**					
PICO 3, PSME 1, ABGR 3	1	—	—	—	—	—	64
PIPO 3, ABGR 5	1	—	—	100	—	—	—
PSME 15, ABGR 20	2	—	—	—	100	—	27
PSME 15, PIEN 3, ABGR 15	1	—	—	—	—	100	9
SELECTION CUT	13	17	5	—	28	—	11
Overstory, pct		**Seedling occurrence (percent) within selection cuts**					
LAOC 3, PSME 38, ABGR 15	1	—	100	—	55	—	22
PIPO 3, ABGR 15	1	—	—	—	—	—	—
PIPO 3, PSME 15, ABGR 15	1	100	—	—	—	—	—
PSME 15	1	—	—	—	14	—	7
PSME 3, PIEN 1, ABGR 38	1	—	—	—	—	—	19
PSME 12, ABGR 5	5	—	—	—	14	—	7
PIEN 15, ABGR 63	1	—	—	—	—	—	4
ABGR 39	2	—	—	—	17	—	41
STAND-DESTROYING WILDFIRE	8	—	15	2	2	5	59
Overstory, pct		**Seedling occurrence (percent) within wildfires**					
No tree cover	2	—	—	—	100	—	3
LAOC 3, ABGR 3	1	—	100	—	—	100	40
PIPO 15, ABGR 15	2	—	—	100	—	—	1
PSME 20	2	—	—	—	—	—	3
ABGR 3	1	—	—	—	—	—	52

[1]Each site contained five sampled microplots.
[2]Percent occurrence of tree seedlings includes the following seedlings from ABGR/ACGL h.t.: 4 PICO, 24 LAOC, 67 PIPO, 114 PSME, 21 PIEN, 185 ABGR.
[3]Not all sample sites were categorized herein as the land manager intended; in this case, two clearcuts had scattered mature *Abies* left standing, creating an *Abies* seed-tree effect.

Pinus contorta seedlings established over a period that ranged from 0 (growing season immediately following the disturbance) to about 20 years (for a 30-year sample period). The average number of years from disturbance to germination was 6. Data from ABGR/VAGL and ABGR/ACGL indicate that *P. contorta* regeneration is highest (55 percent) on clearcut units (table 12). In these clearcuts, most seedlings (75 percent) occurred on sites that had been scarified either for planting or from slash disposal (table 13). Fewer (25 percent) occurred on sites that had received little or no site preparation; however, none were found on residual duff (table 14). Bare mineral soil and moss mat seedbeds both had very efficient RE values for *P. contorta*; litter-covered scarified soil was slightly efficient (table 14). *Polytrichum juniperinum* was the moss most commonly found with conifer seedlings. It usually occurred on scarified soils. The largest proportion (52 percent) of *P. contorta* seedlings was found on sites with moderate (33 to 66 percent) canopy cover (table 15). The canopies of *Spiraea betulifolia, Lonicera utahensis*, and

Table 13—Occurrence of natural seedlings (percent) by site preparation method for ABGR/VAGL h.t.

Species	Site preparation			
	None	Broadcast burn	Scarification: Light	Scarification: Heavy
	Percent			
PICO	25	—	66	9
LAOC[1]	4	14	82	—
PIPO	22	—	39	39
PSME	9	—	73	18
PIEN	29	11	52	8
ABGR	13	14	52	21
	Number			
Microplots	16	11	78	15

[1]Values for *Larix occidentalis* are from ABGR/VAGL and ABGR/ACGL h.t.'s.

Table 14—Occurrence of natural seedlings (percent) and regeneration efficiencies (RE) for seedbeds in ABGR/VAGL h.t.

Species	Litter-covered scarified soil		Bare mineral soil		Moss mat		Rotten wood		Residual duff		Rocks or stumps	
	Pct	*RE*[1]	*Pct*	*RE*	*Pct*	*RE*	*Pct*	*RE*	*Pct*	*RE*	*Pct*	*RE*
PICO	39	0.59	39	2.60	23	1.77	—	—	—	—	—	—
LAOC[2]	32	.46	11	.58	58	8.29	—	—	—	—	—	—
PIPO	46	.70	31	2.07	15	1.15	8	2.67	—	—	—	—
PSME	55	.83	18	1.20	21	1.62	6	2.00	—	—	—	—
PIEN	37	.56	—	—	50	3.85	3	1.00	10	5.00	—	—
ABGR	35	.53	7	.47	15	1.15	14	4.67	28	14.00	—	—
Seedbed occurrence[3]	66		15		13		3		2		1	
Seedbeds with seedlings[4]	29		26		29		6		10		0	

[1]Regeneration efficiency (RE) is the percent occurrence of a seedling species divided by percent area occupied by the seedbed.
[2]Values for *Larix occidentalis* are from ABGR/VAGL and ABGR/ACGL h.t.'s.
[3]Seedbed occurrence is the percent occurrence of a certain seedbed in all 120 microplots.
[4]Seedbeds with seedlings is the percent of microplots with seedlings on a certain seedbed.

Table 15—Occurrence of natural seedlings (percent) by shrub canopy cover for ABGR/VAGL h.t.

Species	Light (0-33%)	Moderate (33-66%)	Heavy (66-100%)
		Percent	
PICO	14	52	35
LAOC[1]	53	41	7
PIPO	40	34	26
PSME	49	17	35
PIEN	25	34	41
ABGR	18	33	49
		Number	
Microplots	30	44	46

[1]Values for *Larix occidentalis* are from ABGR/VAGL and ABGR/ACGL h.t.'s.

Abies grandis had very efficient RE values. *Ribes* spp., *Vaccinium globulare*, and *Rubus parviflorus* RE values were slightly efficient; forbs and *Salix scouleriana* were inefficient for *P. contorta* (table 16). Seedling occurrence was also summarized by tree and shrub layer groups. In terms of tree layer, most *P. contorta* seedlings (59 percent) occurred beneath the PICO l.g., followed by the PSME (29 percent), LAOC (7 percent), and PIPO (5 percent) l.g.'s (table 17). The relative nature of these values apparently reflects the importance of an on-site *P. contorta* seed source for adequate regeneration. In terms of shrub layer, most *P. contorta* seedlings occurred in the VAGL, SASC, and ALSI l.g.'s (30 percent each), followed by the CEVE (6 percent), RIVI (2 percent), and SPBE (2 percent) l.g.'s (table 17). Due to the shallow root system of *Vaccinium*, the VAGL l.g. can endure only light scarification whereas the CEVE and RIVI l.g.'s can result from heavy scarification. These relationships coincide with the

Table 16—Occurrence of natural seedlings (percent) and regeneration efficiencies (RE) by shrub canopies and other microsites[1]

Canopy	Canopy constancy	Area occupied	PICO		LAOC		PIPO		PSME		PIEN		ABGR	
	- - - - - *Percent* - - - - -		*Pct*	*RE*[2]	*Pct*	*RE*	*Pct*	*RE*	*Pct*	*RE*	*Pct*	*RE*	*Pct*	*RE*
None	—	—	3	—	5	—	4	—	3	—	4	—	6	—
Forbs only	99.6	18.3	2	0.11	—	—	1	.07	4	0.21	2	0.10	2	0.11
Graminoids	90.0	7.2	—	—	—	—	—	—	10	[3]1.33	—	—	2	[3].31
Slash	56.8	4.1	—	—	5	1.15	2	.44	3	.71	2	.46	5	1.12
Ribes spp.	46.8	4.8	3	.56	20	4.17	3	.54	3	.56	3	.67	3	.52
Salix scouleriana	36.8	10.4	2	.19	1	.12	3	.29	2	.18	2	.16	4	.40
Spiraea betulifolia	32.8	2.6	7	2.85	—	—	10	4.00	3	.96	1	.31	3	1.27
Vaccinium globulare	31.7	7.5	4	.55	7	.95	6	.77	5	.71	2	.31	4	.48
Ceanothus velutinus	31.1	10.6	—	—	4	.33	3	.25	4	.39	—	—	4	.39
Lonicera utahensis	30.2	3.6	6	1.69	11	2.94	2	.61	4	1.00	5	1.33	2	.53
Rubus parviflorus	24.0	3.5	2	.57	—	—	13	3.69	3	.89	3	.97	2	.49
Rosa spp.	22.3	.6	—	—	—	—	7	12.00	1	2.17	—	—	2	3.17
Physocarpus malvaceus	19.8	3.8	—	—	8	2.16	1	.37	3	.68	1	.16	3	.89
Pinus ponderosa	19.1	4.5	—	—	—	—	2	.49	4	.80	1	.13	3	.71
Abies grandis	14.0	4.0	37	9.30	11	2.65	—	—	2	.43	3	.80	6	1.55
Pseudotsuga menziesii	12.6	1.8	—	—	—	—	—	—	2	.89	—	—	6	3.22
Acer glabrum	12.3	2.6	—	—	—	—	3	1.15	3	1.15	—	—	4	1.58
Symphoricarpos spp.	7.9	1.7	—	—	—	—	—	—	—	—	—	—	—	—
Prunus spp.	7.0	1.4	—	—	—	—	—	—	9	6.07	5	3.79	4	2.79
Alnus sinuata	6.8	3.1	—	—	—	—	—	—	1	.35	14	4.55	3	.97
Pachistima myrsinites	5.1	.6	—	—	29	[3]49.00	—	—	5	[3]8.00	—	—	1	[3]1.83
Amelanchier alnifolia	4.5	.6	—	—	—	—	20	[3]33.17	—	—	—	—	—	—
Sorbus scopulina	3.2	.6	—	—	—	—	—	—	19	[3]32.00	11	[3]17.50	—	—
Picea engelmannii	2.8	.2	—	—	—	—	—	—	—	—	42	[3]210.00	—	—
Sambucus racemosa	2.3	.2	—	—	—	—	—	—	—	—	—	—	5	[3]22.50
Pinus contorta	2.1	.5	—	—	—	—	—	—	—	—	—	—	2	[3]4.40
Larix occidentalis	1.9	.5	—	—	—	—	—	—	10	[3]19.20	—	—	—	—
Shepherdia canadensis	1.9	.4	—	—	—	—	—	—	—	—	—	—	18	[3]44.50
Populus tremuloides	1.9	.1	34	[3]338.00	—	—	—	—	—	—	—	—	2	[3]228.00

[1]This table includes the following seedlings from ABGR/ACGL h.t.: 4 PICO, 24 LAOC, 67 PIPO, 114 PSME, 21 PIEN, 185 ABGR.
[2]Regeneration efficiency (RE) is the percent occurrence of a seedling species divided by percent area occupied by the seedbed.
[3]Discretionary values: large values due to small sample size.

Table 17—Occurrence of natural tree seedlings (percent) by tree and shrub layer groups in ABGR/VAGL h.t.

Layer group	Number of samples	Seedling species				
		PICO	PIPO	PSME	PIEN	ABGR
		Percent				
TREE LAYER GROUPS						
PICO	3	59	—	28	23	8
LAOC	2	7	—	25	17	70
PIPO	13	5	100	25	9	14
PSME	1	29	—	—	51	3
PIEN	1	—	—	—	—	3
ABGR	1	—	—	—	—	—
depauperate	3	—	—	22	—	3
SHRUB LAYER GROUPS[1]						
CEVE	5	6	31	28	12	21
RIVI	8	2	39	44	6	24
SASC	7	30	30	20	10	48
ALSI	2	30	—	—	50	5
SPBE	7	2	—	8	6	1
LOUT	2	—	—	—	17	2
VAGL	1	30	—	—	—	—
		Number				
Tree seedlings sampled under shrubs		20	13	36	36	145

[1]Shrub layer groups include eight plots not used in previous data analysis. These plots were obtained using an older sampling procedure (see methods) and were used to supplement layer groups for which little or no data had been obtained using the new sampling method.

much higher occurrence of *P. contorta* seedlings on lightly scarified areas than on heavily scarified areas (table 13).

The sample data suggest that the best silvicultural and site preparation method for *P. contorta* is clearcutting with light scarification. These data agree with those of previous studies (Boe 1956; Cochran 1953; Dahms 1963; Day and Duffy 1963; Tackle 1956; Trappe 1959). In most cases, if *P. contorta* slash is distributed over the scarified soil such that the cones lie on or just above the soil, soil surface temperatures will be adequate to open serotinous cones (Lotan 1964). But the amount of cone serotiny is relatively low. Light scarification treatments that maintain the VAGL l.g. or promote development of the SASC l.g. are the most effective. Although *Salix* is an inefficient RE species for *P. contorta*, occurrence of *P. contorta* seedlings is high in the SASC l.g., possibly due to other higher RE value species or the fact that light scarification favors seedlings of both *Salix* and *P. contorta*. If the treated stand has high initial coverage of *Salix*, the extensive canopy cover that may occur from sprouts of *Salix* following clearcutting will likely inhibit *P. contorta* establishment and growth. Broadcast burns that produce the CEVE l.g. may promote establishment of *P. contorta* seedlings provided a seed crop exists at the time of burning; however, extremely hot broadcast burns that produce a dense cover of *Ceanothus* may preclude establishment of *P. contorta* in future years.

Larix occidentalis seedlings were scarce in the ABGR/VAGL h.t.; only one seedling occurred in the sample plots. Data from the ABGR/ACGL h.t. showed that *Larix* germination ranged from 0 to 14 years following disturbance, with an average of 1 year. Most seedlings (68 percent) occurred in seed-tree cutting units, and 91 percent of those seedlings occurred on sites with *Larix* seed-trees (table 12). Considerably fewer seedlings (12 percent) were found in clearcuts, while 5 percent were found in the only selection cut stand that had *Larix* as an overstory component. A small portion of the sample stands had been disturbed by wildfire, and 15 percent of the *Larix* seedlings occurred in one such stand. The disturbance in these wildfire stands, however, was much older than the sampled silvicultural treatments, and the large occurrence of seedlings may be due to a longer developmental period rather than type of disturbance. In terms of site preparation, most seedlings (82 percent) occurred on sites that had been lightly scarified (table 13). Only moss mats had a very efficient RE value for *Larix* (table 14). Bare mineral soil and litter-covered scarified soils were both slightly efficient. The largest proportion of seedlings (53 percent) was found on sites with a light shrub canopy cover (table 15). Logging slash, *Ribes* spp., *Lonicera utahensis*, *Physocarpus malvaceus*, and *Abies grandis* all had very efficient RE values for *Larix* (table 16); *Vaccinium globulare* was moderately efficient, *Ceanothus velutinus* was slightly efficient, and *Salix scouleriana* was inefficient.

Seed-tree cuts with *Larix* seed-trees and light scarification (Boyd and Deitschman 1969; Haig and others 1941; Schmidt 1969) will likely promote establishment of natural *Larix* regeneration. Even though only one seedling was found in ABGR/VAGL, data from ABGR/ACGL indicate that canopies of *Ribes*, *Lonicera*, and *Vaccinium* may enhance establishment of *Larix*. Therefore site treatments such as light scarification, which favor these shrub species, may also enhance establishment of *Larix* seedlings.

Pinus ponderosa germination averaged about 6 years and ranged from 0 to 19 years following disturbance. Most

of the regeneration (75 percent) was found on seed-tree cutting units. All of the seedlings occurred on sites having a *P. ponderosa* seed source nearby (table 12). No natural regeneration was found in partially cut stands even though two stands had *P. ponderosa* in the overstory. Scarification treatments produced most of the natural regeneration (78 percent) (table 13). Very efficient RE values were found for rotten wood, bare mineral soil, and moss mat seedbeds (table 14). Litter-covered scarified soil was found to be slightly efficient. Rotten wood from logs and stumps was found both on sites with and without site preparation. On areas with site preparation, scarification most often occurred around intact logs or stumps, which then decayed in place. This is in contrast to a few sites on which already decayed logs or stumps were incorporated into mineral soil during scarification. Overall, scarification treatments resulted in more natural regeneration of all species probably by reducing the coverage of residual duff; but when rotten wood is present, it may provide a more beneficial rooting environment than mineral soil (Harvey 1982). Nevertheless, manipulating logs and stumps to increase natural regeneration is not a practical management option.

Many *P. ponderosa* seedlings occurred beneath some shade. Forty percent were found under a light shrub canopy cover; 34 percent occurred under moderate cover and 26 percent under heavy canopy cover, respectively (table 15). Canopies of *Rubus parviflorus, Spiraea betulifolia, Rosa* spp., and *Acer glabrum* had very efficient RE values (table 16). *Vaccinium globulare* was moderately efficient, and several species were slightly efficient. In terms of tree canopy all natural regeneration was found in the PIPO l.g. (table 17). In terms of shrub canopy, *P. ponderosa* seedling occurrence was highest in the RIVI l.g. (39 percent) and slightly lower in the CEVE (31 percent) and SASC (30 percent) l.g.'s. All three of these layer groups often result from thorough scarification.

On some sites, seed caches may play an important role in *P. ponderosa* establishment. In the Oregon Cascade Range, West (1968) found that 15 percent of the *P. ponderosa* seedlings resulted from rodent caches. In central Idaho, McConkie and Mowat (1936) found that a similar proportion (14 percent) of seedlings resulted from caches. Medin (1984) indicated that the yellowpine chipmunk (*Eutamias amoenus*) may be responsible for many of the caches found in central Idaho, although the Clark's nutcracker (*Nucifraga columbiana*) may also be involved (Lanner 1980). In ABGR/VAGL, 17 percent of the *P. ponderosa* regeneration apparently established from seed caches. The incidence of seed caches was highest on sites with *R. parviflorus*, and the number of caches increased as the coverage of *Rubus* increased. This may have resulted from increased rodent activity where the *Rubus* occurs because chipmunks feed on *Rubus* berries (Martin and others 1951; Van Horne 1982), or because the *Rubus* provides cover for the chipmunks.

Pinus ponderosa seed-tree cuts (Foiles and Curtis 1973; Heidmann and others 1982) followed by scarification (Baker 1942; Harrington and Kelsey 1979; Shearer and Schmidt 1970) are the most favorable condition for establishment of natural *P. ponderosa* seedlings. The most effective site treatment is one which promotes establishment of the RIVI l.g. and provides some cover of *Spiraea* and *Rubus*. Broadcast burns which produce the CEVE l.g. may encourage natural *P. ponderosa* establishment provided a seed crop exists at the time of burning. Broadcast burns which produce a dense *Ceanothus* cover may preclude pine establishment from subsequent seed crops.

Pseudotsuga menziesii germination occurred from 0 to 21 years following disturbance and averaged about 6 years. Most of the regeneration (43 percent) was found on seed-tree cutting units; however, none of these sites contained *Pseudotsuga* seed-trees (table 12). Twenty-eight percent of the seedlings established in partially cut stands where 83 percent of the seedlings occurred in stands with *Pseudotsuga* in the overstory. Scarification treatments produced the most regeneration (91 percent) (table 13). Rotten wood, moss mats, and bare mineral soil seedbeds had very efficient RE values for *Pseudotsuga* (table 14). Litter-covered scarified soil was moderately efficient. Most seedlings (49 percent) were found under a light shrub canopy; 17 percent occurred under a moderate canopy cover and 35 percent under a heavy canopy (table 15). Very efficient RE values occurred for *Lonicera utahensis, Rosa* spp., *Prunus* spp., and *Acer glabrum* (table 16). *Spiraea betulifolia, Rubus parviflorus, Pinus ponderosa*, and *P. menziesii* were moderately efficient and slash, *Ribes* spp., *Vaccinium globulare, Ceanothus velutinus, Physocarpus malvaceus, Abies grandis*, and *Alnus sinuata* were slightly efficient. *Salix scouleriana* had an inefficient RE value. In terms of tree layer succession, most *Pseudotsuga* seedlings (28 percent) were found in the PICO l.g. although occurrences were only slightly lower in the LAOC (25 percent), PIPO (25 percent), and depauperate (22 percent) l.g.'s (table 17). In terms of shrub layer succession, *Pseudotsuga* regeneration was highest (44 percent) in the RIVI l.g. Twenty-eight percent occurred in the CEVE l.g. and 20 percent occurred in the SASC l.g.

The sample data suggest that optimum conditions for natural regeneration of *Pseudotsuga* would be either a seed-tree cut (Williamson 1973) with at least 16 percent tree canopy cover, and a *Pseudotsuga* seed source nearby, or a selection cut in the LAOC or PICO tree layer group with *Pseudotsuga* in the overstory. Thorough scarification which produces an RIVI l.g. will likely provide the best microsite for seedling establishment. The best seedbeds were bare soil and scarified soil covered with a moss mat. Broadcast burns that produce the CEVE l.g. with light or moderate coverages of *Ceanothus* may facilitate *Pseudotsuga* regeneration.

Picea engelmannii germinated over a period of 0 to 22 years following disturbance; the average was about 6 years. Regeneration was highest (38 percent) in a single shelterwood cut, which was the only sampled shelterwood having *Picea* in the overstory (table 12). Regeneration on seed-tree cutting units was slightly lower (34 percent). In this case, 95 percent of the seedlings established in a stand having *Picea* and *Larix* seed-trees, with a combined canopy cover of about 18 percent. Some seedlings (23 percent) were also found in clearcuts. Many of the seedlings (60 percent) occurred on scarified sites (table 13). The rest of the seedlings were found on sites that had been broadcast burned (11 percent) or had no site preparation (29 percent). Residual duff, rotten wood, and moss-mat

seedbeds had very efficient RE values (table 14). Litter-covered scarified soil was slightly efficient. The largest proportion of seedlings (41 percent) was found on sites with heavy canopy cover, but the occurrence of seedlings decreased only slightly with decreasing canopy cover (table 15). *Lonicera utahensis*, *Prunus* spp., and *Alnus sinuata* had very efficient RE values (table 16). Moderately efficient RE values were found for *Rubus parviflorus* and *Abies grandis*. Slash, *Ribes* spp., *Spiraea betulifolia*, and *Vaccinium globulare* were slightly efficient. Inefficient RE values occurred for forbs, *Salix scouleriana*, *Physocarpus malvaceus*, and *Pinus ponderosa*. Most of the regeneration (51 percent) was found in the PSME l.g. (table 17). The rest of the regeneration occurred in the PICO (23 percent), LAOC (17 percent), and PIPO (9 percent) l.g.'s. In terms of shrub layer succession, more *Picea* seedlings were found in the ALSI l.g. (50 percent) than in the LOUT (17 percent), CEVE (12 percent), SASC (10 percent), or RIVI (6 percent) l.g.'s.

Shelterwood cuts (Day 1963, 1964; Day and Duffy 1963; Roe and others 1970) in a PSME or PICO tree layer type containing *Picea*, or seed-tree cuts having *Picea* in the overstory and at least 18 percent canopy cover, should provide an adequate tree canopy for *Picea* regeneration. Scarification will likely create the best seedbed for obtaining *Picea* regeneration (Bernsten 1955; Boyd and Deitschman 1969; Fiedler and others 1985; Roe and others 1970). As with the other previously mentioned species, scarification enhances *Picea* establishment; however, *Picea* also establishes on residual duff. A combination of heavy canopy cover and residual duff may favor *Picea* and may preclude other tree regeneration except *A. grandis*. Scarification treatments that result in, or maintain, the LOUT or ALSI l.g.'s and retain some residual duff should provide favorable microsites. Hot broadcast burns that produce a heavy canopy cover of *Ceanothus* may encourage establishment of *Picea* over other species.

Abies grandis germination ranged from 0 to 30 years following disturbance, averaging about 7 years. Most seedlings (59 percent) occurred in two old wildfire-disturbed stands; there was little difference between occurrence of seedlings among the artificially disturbed stands (table 12). Selection cut stands and clearcuts contained 11 percent of the seedlings; seed-tree cuts had 10 percent, and shelterwood cuts had 9 percent. In terms of site treatment, most seedlings (73 percent) occurred on scarified sites (table 13). In contrast, fewer seedlings were found in broadcast burned (14 percent) and no site preparation (13 percent) areas. Very efficient RE values were found for residual duff, rotten wood, and moss mats (table 14). Most seedlings (49 percent) occurred under heavy canopy cover (table 15). Seedling occurrence decreased with decreasing canopy cover; only 18 percent of the seedlings were found under light cover. Very efficient RE values occurred for slash, *Spiraea betulifolia*, *Rosa* spp., *Abies grandis*, *Pseudotsuga menziesii*, *Prunus* spp., and *Acer glabrum* (table 16). *Physocarpus malvaceus* and *Alnus sinuata* were moderately efficient. Slightly efficient values were found for *Ribes* spp., *Salix scouleriana*, *Vaccinium globulare*, *Lonicera utahensis*, *Rubus parviflorus*, and *Pinus ponderosa*. In terms of tree cover, most of the seedlings (70 percent) established in one stand in the LAOC l.g. (table 17). Fewer were found in the PIPO (14 percent) and PICO (8 percent) l.g.'s. The PSME and PIEN l.g.'s each contained only 3 percent. In terms of shrub layer, the SASC l.g. contained the most *A. grandis* seedlings (48 percent). The remaining seedlings established in the RIVI (24 percent), CEVE (21 percent), ALSI (5 percent), LOUT (2 percent), and SPBE (1 percent) l.g.'s (table 17).

Almost any silvicultural method can be used to regenerate *A. grandis*. Scarification, especially, will enhance *A. grandis* seedling establishment (Haig and others 1941). As with *Picea, A. grandis* also establishes on residual duff. A combination of heavy canopy cover and residual duff will likely result in more *A. grandis* regeneration than that of other species except *Picea*. Site treatments that favor the CEVE, RIVI, or SASC l.g.'s are most apt to produce *A. grandis* seedlings.

SUMMARY OF SHRUB LAYER SECTION

Shrub layer classification in ABGR/VAGL consists of seven layer groups and 28 layer types. The classification is based on seven indicator species and three alternates.

Ceanothus velutinus indicates early seral conditions. Seed stored in the soil remains viable for centuries and germinates when it is heated by fire. The species is widespread in ABGR/VAGL, and its absence following severe burning may indicate either wet sites suitable for *Picea* or frost pockets better suited for *Pinus contorta* than *P. ponderosa*. *Ceanothus* serves as an indicator of seven layer types. Six of these result from either wildfire or different intensities of burning following clearcutting or from scarification. One layer type, CEVE-RIVI, results mainly from severe scarification. All seven depend somewhat on composition of the predisturbance shrub layer as well as disturbance intensity.

Ribes viscosissimum and *R. lacustre* also indicate early seral shrub layers and also store seed in the soil. The buried seed germinates readily following clearcutting and scarification without burning. *Ribes lacustre* occurs mainly on the wetter sites suitable for *Picea*. *Ribes* serves as an indicator of six layer types, which result mainly from different intensities of scarification in different predisturbance shrub layers. Thorough scarification most often results in the RIVI-RIVI layer type, which creates the least competition for planted trees over time of any shrub layer in ABGR/VAGL.

Salix scouleriana acts as a midseral species in ABGR/VAGL and can resprout vigorously following clearcutting. Its windblown seed is most apt to establish on well-scarified soil, especially along contour ditches or terraces. In clearcuts, properly planted *Pinus ponderosa* can usually overtop *Salix* seedlings, but are severely outcompeted by *Salix* that resprouts from residual stumps. High densities of *Salix* in uncut stands may preclude success of pine plantations following clearcutting.

Alnus sinuata acts as a midseral species in ABGR/VAGL and occurs mainly on the wetter sites, which are often suitable for *Picea*. The *Alnus* establishes following clearcutting or wildfire on moist mineral soil and can resprout from stumps. The stump sprouts and possibly seedlings may outcompete planted pines.

Spiraea betulifolia and the alternate indicators *Symphoricarpos albus* and *Rubus parviflorus* are rhizomatous late seral shrubs that are seldom eradicated during scarification. Some SPBE layer types may result from clearcutting and scarification without burning. All three layer types can result from uninterrupted succession.

Lonicera utahensis is an indicator of late seral conditions and often survives logging and site preparation treatments by resprouting from residual root crowns. Apparently its seed is not stored in the soil.

Vaccinium globulare is a climax species in ABGR/VAGL. This shallow-rooted, rhizomatous shrub is easily removed by scarification. This *Vaccinium* has high forage value for deer, elk, and bear.

Shrub layer types vary considerably in their forage value for deer, elk, and bear. Most early seral CEVE layer types have at least moderate forage value for deer and elk but considerably less for bear. The midseral SASC-VAGL and ALSI-VAGL layer types have the greatest forage value for bear. Shrub forage values are low to moderate for sheep and low for cattle throughout ABGR/VAGL succession.

Natural *Pinus contorta* seedlings should be successful in lightly scarified clearcuts having a seed source nearby. A shrub canopy of *Spiraea* might benefit *P. contorta* seedlings; *Salix* and forbs are apt to be detrimental.

Larix is most apt to regenerate from seed-tree cuts and light scarification. A 3 percent canopy cover of *Larix* should provide an adequate seed source. The shrub canopies of *Ribes* and *Lonicera* may enhance *Larix* establishment.

Natural *Pinus ponderosa* should regenerate best from a seed-tree cut and thorough scarification. A 3 percent canopy cover of *P. ponderosa* should provide an adequate seed source in ABGR/VAGL. The shrub canopies of *Rubus, Rosa*, and *Spiraea* may benefit the pine seedlings; *Ceanothus, Salix*, and forbs may be detrimental. On some sites the seed caches of chipmunks and the Clark's nutcracker may be important to pine establishment.

Pseudotsuga is most apt to regenerate in the partial shade of a tree canopy with a seed source nearby. At least 16 percent tree canopy should be an adequate cover for *Pseudotsuga*. Well-scarified soil or scarified soil that has acquired a moss mat appears to be the best seedbed. The shrub canopies of *Prunus, Rosa, Acer*, and *Lonicera* may facilitate *Pseudotsuga* establishment.

Picea should regenerate best in the partial shade of a tree canopy; at least 18 percent cover should be adequate. Scarified soil that has acquired a moss layer is the best seedbed. *Alnus, Prunus, Lonicera*, and *Rubus* may benefit *Picea* seedlings; *Salix* and forbs may be detrimental.

Abies grandis seedlings appear to have less specific microsite requirements than the other tree species. Scarified soil, rotten wood, and residual duff are all adequate seedbeds. Most seedlings establish under a heavy shrub canopy. The canopies of *Rosa, Prunus*, and *Spiraea* may provide added benefit.

The Herb Layer

The herb layer is more complex and less understood than the tree and shrub layers. Modal conditions of seral stages are evident but more variable because there are more species. More species imply potentially more herb layer types, but the relative increase has been less than expected. It is possible that more kinds of disturbance are needed to generate the broad array of layer types. Still, the following herb layer classification appears to follow logical successional sequences even though it may eventually need more refinement than the tree or shrub layer classifications.

Relative successional amplitudes of important herb layer species (fig. 19) were derived by developing hypotheses for each species followed by testing through many field observations as well as data analysis. Because succession in the herb layer progresses more rapidly than the tree or shrub layer, successional amplitudes for some herb layer species can also be derived from the permanent plot records of Stickney (1980, 1985). As in the tree and shrub layer, successional amplitudes of herb layer species are meaningful only in a relative sense, and the greatest accuracy lies with those amplitudes that are farthest apart. For instance, species indicating the Annuals layer group clearly have less amplitude than *Thalictrum* (fig. 19). But there is less certainty to the relative amplitudes of adjacent species such as *Fragaria* and *Carex geyeri*.

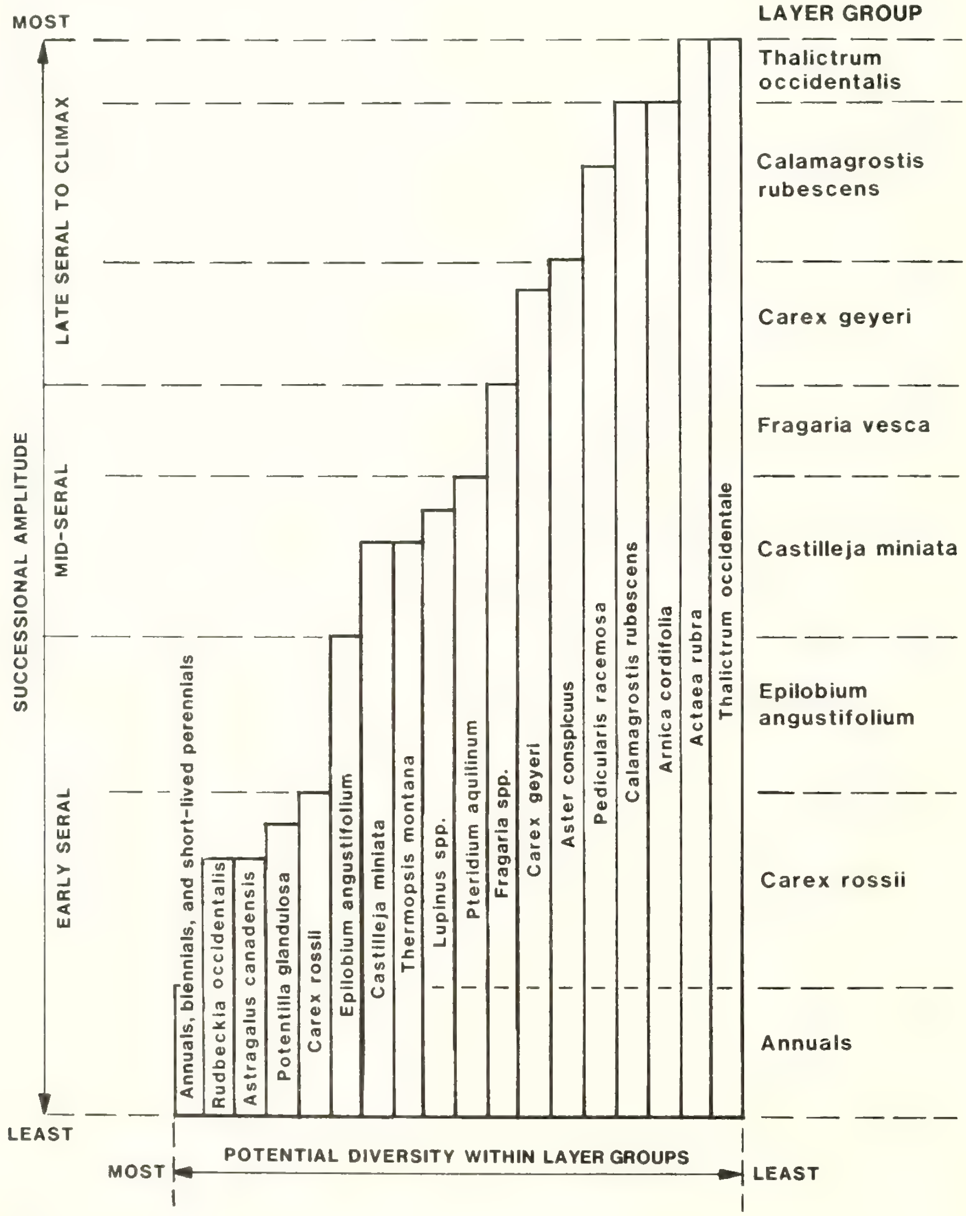


Figure 19—Relative successional amplitudes of important herb layer species in ABGR/VAGL h.t.

Figure 19 lists only the important species, which were those that showed greater than 5 percent coverage somewhere in the data. Many unlisted species may be present in lesser amounts, and some potentially important species may yet be found. Appendix C shows that species diversity may be highest in early seral stages (as figure 19 indicates), but total herb layer coverages may be greatest in midseral to late seral stages, a feature noted previously in a similar study (Hann 1982).

The relative successional amplitudes in figure 19 provide a basis for the present herb layer classification (fig. 20). This classification consists of eight layer groups; the full data set appears in appendix C. Although the classification is based on 64 sample plots, some layer groups have little data. Data in the Annuals layer group are lacking because these conditions usually occur within 5 years following disturbance, and recently disturbed sites were not a sampling objective. Other layer types may be found with more reconnaissance, may appear only after uncommon disturbances, or may be rare under any circumstance.

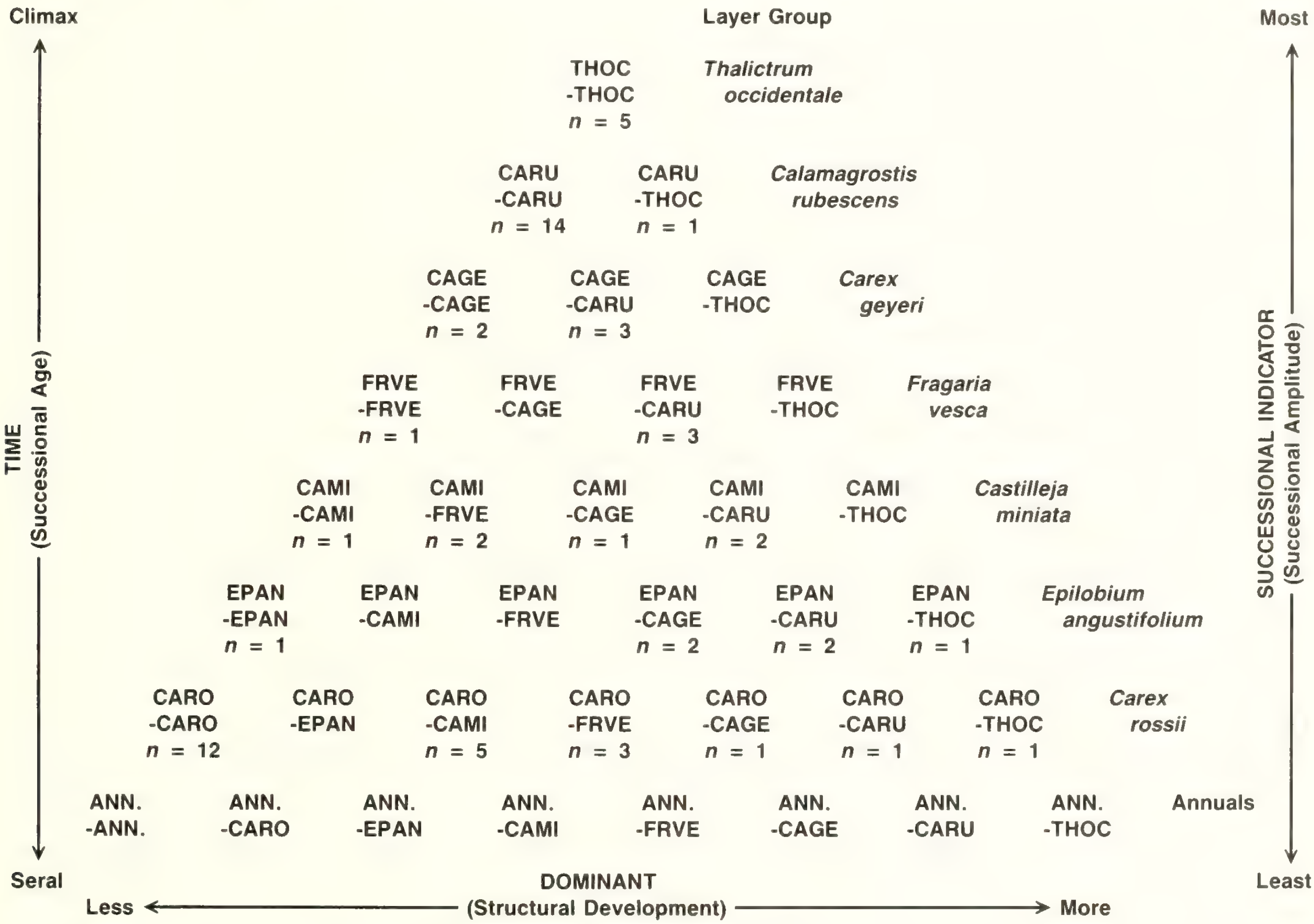


Figure 20—Succession classification diagram of the herb layer in the ABGR/VAGL h.t. (n = number of samples in each layer type).

The key to herb layer types (table 18) contains numerous alternate indicator species. Much of this lumping is necessary to maintain a workable number of units in this diverse vegetative layer. In some cases, combining indicator species has reduced uniformity within the unit because the species represent minor differences of environment or successional pattern within the habitat type. In other cases, the alternate indicators are common environmental and successional equivalents and the classified unit retains substantial uniformity. In all cases the lumped species appear to have similar successional amplitudes (fig. 19).

Early seral annuals, biennials, and short-lived perennials were grouped into one unit because there appears to be no practical reason to recognize them individually. *Rudbeckia*, *Potentilla glandulosa*, and *Astragalus canadensis* were grouped with *Carex rossii* because of similar responses to scarification. *Lupinus* spp. and *Thermopsis montana* were grouped with *Castilleja miniata* due to similar responses to livestock grazing. *Pteridium* occurred in only one sample plot and was subjectively grouped with *Castilleja*. *Carex geyeri* and *Aster conspicuus* were combined as late seral indicators; *Arnica cordifolia* and *Pedicularis racemosa* were grouped with *Calamagrostis rubescens* as near-climax indicators. *Actaea rubra* was grouped with *Thalictrum* as a climax associate.

Table 18—Key to herb layer groups and layer types, with ADP codes, in ABGR/VAGL h.t.

		ADP codes
1. Annuals, biennials, and short-lived perennials (see layer group description for species) well represented[1] either individually or collectively (Choose first condition that fits)	Annuals Layer Group	900
1a. The above species dominant	ANN.-ANN. Layer Type	900.900
1b. *Carex rossii* (incl. *Potentilla glandulosa*, *Astragalus canadensis*, *Iliamna*, and *Rudbeckia*) dominant or codominant	ANN.-CARO Layer Type	900.311
1c. *Epilobium angustifolium* dominant or codominant	ANN.-EPAN Layer Type	900.459
1d. *Castilleja* spp. (incl. *Thermopsis*, *Lupinus*, and *Pteridium*) dominant or codominant	ANN.-CAMI Layer Type	900.438
1e. *Fragaria* spp. dominant or codominant	ANN.-FRVE Layer Type	900.465
1f. *Carex geyeri* (incl. *Aster conspicuus*) dominant or codominant	ANN.-CAGE Layer Type	900.309
1g. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*, dominant or codominant	ANN.-CARU Layer Type	900.307
1h. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	ANN.-THOC Layer Type	900.547
1. Annuals, biennials, and short-lived perennials poorly represented	2	
2. *Carex rossii* (incl. *Potentilla glandulosa*, *Astragalus canadensis*, *Iliamna*, and *Rudbeckia*) well represented (Choose first condition that fits)	CARO Layer Group	311
2a. The above species dominant	CARO-CARO Layer Type	311.311
2b. *Epilobium angustifolium* dominant or codominant	CARO-EPAN Layer Type	311.459
2c. *Castilleja* spp. (incl. *Thermopsis*, *Lupinus*, and *Pteridium*) dominant or codominant	CARO-CAMI Layer Type	311.438
2d. *Fragaria* spp. dominant or codominant	CARO-FRVE Layer Type	311.465
2e. *Carex geyeri* (incl. *Aster conspicuus*) dominant or codominant	CARO-CAGE Layer Type	311.309
2f. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*) dominant or codominant	CARO-CARU Layer Type	311.307
2g. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	CARO-THOC Layer Type	311.547
2. *Carex rossii* (incl. *Potentilla glandulosa*, *Astragalus canadensis*, *Iliamna*, and *Rudbeckia*) poorly represented	3	
3. *Epilobium angustifolium* well represented (Choose first condition that fits)	EPAN Layer Group	459
3a. *Epilobium* dominant	EPAN-EPAN Layer Type	459.459
3b. *Castilleja* spp. (incl. *Thermopsis*, *Lupinus*, and *Pteridium*) dominant or codominant	EPAN-CAMI Layer Type	459.438
3c. *Fragaria* spp. dominant or codominant	EPAN-FRVE Layer Type	459.465
3d. *Carex geyeri* (incl. *Aster conspicuus*) dominant or codominant	EPAN-CAGE Layer Type	459.309
3e. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*) dominant or codominant	EPAN-CARU Layer Type	459.307
3f. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	EPAN-THOC Layer Type	459.547
3. *Epilobium angustifolium* poorly represented	4	
4. *Castilleja* spp. (incl. *Thermopsis*, *Lupinus*, and *Pteridium*) well represented (Choose first condition that fits)	CAMI Layer Group	438
4a. The above species dominant	CAMI-CAMI Layer Type	438.438
4b. *Fragaria* spp. dominant or codominant	CAMI-FRVE Layer Type	438.465
4c. *Carex geyeri* (incl. *Aster conspicuus*) dominant or codominant	CAMI-CAGE Layer Type	438.309
4d. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*) dominant or codominant	CAMI-CARU Layer Type	438.307
4e. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	CAMI-THOC Layer Type	438.547
4. *Castilleja* spp. (incl. *Thermopsis*, *Lupinus*, and *Pteridium*) poorly represented	5	

(con.)

Table 18 (Con.)

		ADP codes
5. *Fragaria* spp. well represented (Choose first condition that fits)	FRVE Layer Group	465
5a. *Fragaria* spp. dominant	FRVE-FRVE Layer Type	465.465
5b. *Carex geyeri* (incl. *Aster conspicuus*) dominant or codominant	FRVE-CAGE Layer Type	465.309
5c. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*) dominant or codominant	FRVE-CARU Layer Type	465.307
5d. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	FRVE-THOC Layer Type	465.547
5. *Fragaria* spp. poorly represented	6	
6. *Carex geyeri* (incl. *Aster conspicuus*) well represented (Choose first condition that fits)	CAGE Layer Group	309
6a. The above species dominant	CAGE-CAGE Layer Type	309.309
6b. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*) dominant or codominant	CAGE-CARU Layer Type	309.307
6c. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	CAGE-THOC Layer Type	309.547
6. *Carex geyeri* (incl. *Aster conspicuus*) poorly represented	7	
7. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis racemosa*) well represented (Choose first condition that fits)	CARU Layer Group	307
7a. The above species dominant	CARU-CARU Layer Type	307.307
7b. *Thalictrum occidentale* (incl. *Actaea*) dominant or codominant	CARU-THOC Layer Type	307.547
7. *Calamagrostis rubescens* (incl. *Arnica* and *Pedicularis*) poorly represented	8	
8. *Thalictrum occidentale* (incl. *Actaea*) well represented	THOC Layer Group	547
8a. The above species dominant	THOC-THOC Layer Type	547.547
8. *Thalictrum occidentale* (incl. *Actaea*) poorly represented	Depauperate or unclassified layer type.	

[1]"Well represented" means ≥5 percent canopy coverage; "dominant" refers to greatest canopy coverage; "codominant" refers to nearly equal canopy coverage.

ANNUALS LAYER GROUP (ANN. L.G.)

Annuals, mainly species of *Epilobium* and *Gayophytum* and occasionally *Polygonum*, *Collomia*, and *Cryptantha*, can develop high coverages on newly exposed soil in full sunlight. These taxa have little competitive ability, and their annual nature makes them vulnerable to replacement by any perennial. Likewise, biennials such as *Verbascum* and *Cirsium vulgare* and the short-lived perennials *Phacelia* and *Gnaphalium* must reestablish frequently in order to maintain high coverages. Without recurring disturbance these taxa are also easily replaced as succession advances. Relative amounts of these early seral colonizers vary considerably following disturbance and appear to be mainly a function of available seed. The Annuals layer group represents the earliest seral conditions of the herb layer and is usually replaced within the first 5 years following disturbance; however, it can be maintained by intense livestock use.

CAREX ROSSII LAYER GROUP (CARO L.G.)

Carex rossii is a nonrhizomatous sedge that stores its seed in the soil or duff (Kramer 1984). It sprouts readily following scarification but responds poorly to burning. On thoroughly scarified sites, *C. rossii* can dominate the herb layer and remain well represented until replaced by taller species. In spring, it provides some forage for large herbivores.

The perennial forb *Potentilla glandulosa* often associates with *C. rossii* but in ABGR/VAGL is less common than the *Carex*. It is nonrhizomatous and intolerant of shade. In sunlight, it flowers readily and produces large numbers of seed, which are stored in the soil (Kramer 1984) and germinate following scarification. The scarification can result from either mechanical treatment of the site or heavy livestock use. *Potentilla* seems to be less palatable to livestock than most associated herbs and can increase under grazing to the point of being the only species that is well represented on the site. This response is most evident on granitic soils; on nongranitic soils reaction to grazing is less pronounced but still evident from both sheep and cattle use.

Rudbeckia occidentalis is a nonrhizomatous perennial, with successional responses similar to those of *Potentilla*. One obvious difference, however, is that *Rudbeckia* tends to be a more successful invader on basalt parent materials whereas *Potentilla* is more successful on granitics. Because both types of soils are common in ABGR/VAGL, *Rudbeckia* is lumped as an alternate indicator of the CARO l.g.

Astragalus canadensis is a shade-intolerant, rhizomatous forb with seed that can be stored in the soil. The seed germinates readily in clearcuts following burning or scarification. *Astragulus* appeared only occasionally in ABGR/VAGL but when found was usually well represented in clearcut areas.

The above species respond mainly to scarification and, when well represented, indicate early seral stages of herb layer succession. As a result, this layer group may persist for many years if influenced by livestock but declines rapidly where shade develops. Most sample stands in this

layer group were disturbed less than 15 years ago (appendix C). Those disturbed more than 15 years ago have received repeated light to moderate livestock use. Six of the seven possible layer types in the CARO layer group (fig. 20) were encountered during field sampling. The most common of these, CARO-CARO, resulted from intensive machine scarification often followed by cattle grazing. Contour stripping and pile-and-burn operations were by far the most common site treatments throughout the CARO l.g.; grazing, mainly by cattle, was also common.

EPILOBIUM ANGUSTIFOLIUM LAYER GROUP (EPAN L.G.)

Epilobium angustifolium is a rhizomatous perennial that can establish readily from windblown seed. In open areas created by stand-destroying wildfire, it characteristically colonizes bare soil and forms extensive colonies that bloom profusely (Stickney 1985). *Epilobium*, however, does not always need burned areas for establishment. In clearcuts, it often appears on dozer-piled debris, burned or unburned, where soil and debris have been mixed. The required substrate for *Epilobium* is deep, loose soil, usually exposed by either fire or logging.

The EPAN l.g. represents early seral stages of herb layer succession (fig. 19). Of the six possible layer types, four were encountered (fig. 20). All sample plots resulted from clearcutting and at least some scarification 6 to 21 years ago. None of these sites was being grazed by livestock.

CASTILLEJA MINIATA LAYER GROUP (CAMI L.G.)

Castilleja miniata is a woody-based forb with some tolerance for light shade and grazing. In ABGR/VAGL, it occasionally develops relatively high coverages in lightly grazed stands of patchy timber or scattered tall shrubs. *Castilleja applegatei* may also be present on these sites and is considered a successional equivalent of *C. miniata*.

Thermopsis montana is a rhizomatous forb with seeds that can be stored in forest soil (Kramer 1984). Its tolerance for shade and grazing appears similar to that of *C. miniata*, and it occurs in similar site conditions. For these reasons, it was included in the CAMI l.g.

Species of *Lupinus*, mainly *L. laxiflorus* and *L. sericeus*, are occasionally well represented in ABGR/VAGL. These are nonrhizomatous deep-rooted forbs that can persist under light shade but attain their best development in full sun. Their relatively heavy seed is not apt to disperse widely and is likely stored in the soil. Responses to specific disturbances are not clear, but burning and grazing probably increase their numbers.

Pteridium is a rhizomatous fern capable of developing extensive colonies, especially with repeated burning. It can dominate forest openings for many decades, even without burning, and often maintains relatively pure stands. This latter trait has implicated *Pteridium* with allelopathic capability, a feature substantiated by Stewart (1975), Horsley (1977), and del Moral and Cates (1971). Apparently the senescent fronds produce the greatest inhibitory effects on certain herbaceous and woody vegetation but have not yet been shown to substantially inhibit conifers. Although it often grows vigorously in full sun, *Pteridium* can also increase under light shade but declines under a mature coniferous canopy. Because *Pteridium* is uncommon in ABGR/VAGL, it is not likely that it represents a complete layer group. For this reason it was subjectively lumped with the CAMI l.g. as the most similar successional stage.

The CAMI l.g. is a midseral stage that often replaces the CARO l.g. as grazing pressure declines. It generally appears in openings between tall shrubs or in patches of timber that deter livestock use. Further succession often leads to the FRVE l.g. Although the CAMI l.g. may occur throughout most of the ABGR/VAGL h.t., it is more common toward the drier extremes. Four of the five possible layer types in the CAMI l.g. were found (fig. 20). Only the CAMI-THOC layer type was not found but may occur following clearcutting and light scarification of a *Thalictrum*-dominated herb layer.

FRAGARIA VESCA LAYER GROUP (FRVE L.G.)

Fragaria vesca and *F. virginiana* can develop substantial coverages through their stoloniferous growth habit. This happens most frequently beneath a light canopy of trees or tall shrubs where partial shade has reduced competition from earlier successional herbs. Trampling from grazing animals can reduce the coverage of *Fragaria*, especially *F. vesca*. On cutover sites that are being heavily grazed, *Fragaria* often achieves notable development beneath the protection of large shrubs while the shrub interspaces contain mostly *Potentilla* and other species more tolerant of grazing. *Fragaria virginiana*, however, can endure light to moderate grazing pressure. In ABGR/VAGL, it tends to occur on the more gentle terrain generally associated with frost pockets and *Pinus contorta* sites. In contrast, *F. vesca* tends to be more abundant on steeper terrain that is better suited for *Pinus ponderosa*. Because both *Fragaria* species can also be well represented on the same site, they should not be used as absolute indicators of tree species suitability. Apparently *Fragaria vesca* can store small amounts of viable seed in the soil (Kramer 1984).

The FRVE layer group represents a midseral stage of forb layer succession and consists of four layer types in ABGR/VAGL. Two of these have been sampled (fig. 20). Most of the FRVE layer types sampled are the successional result of clearcut areas that were scarified 12 to 14 years ago. One sample resulted from a broadcast burn operation 18 years ago. Little or no grazing was evident on most of these sites.

CAREX GEYERI LAYER GROUP (CAGE L.G.)

Carex geyeri is a moderately shade-tolerant sedge found in many habitat types. It tends to grow in a bunch form, especially on dry granitic substrates, but also develops a loose rhizomatous form on more moist sites. Its extensive root system is an effective soil stabilizer, and the plant can resprout following light scarification. It has some ability to store seed in the soil (Kramer 1984). The stored seed apparently germinates following clearcutting and scarification. In spring, *C. geyeri* is one of the first plants

to produce new growth, which has considerable forage value for elk and bear (appendix C). This *Carex* generally persists in older stands but with increasing shade gives way to its common associates, *Calamagrostis rubescens*, *Arnica*, or *Thalictrum*. For this reason *C. geyeri* represents late seral stages of ABGR/VAGL herb layer succession (fig. 19).

Aster conspicuus is a moderately shade-tolerant forb that can maintain extensive colonies beneath pine and Douglas-fir. It can increase vegetatively by rhizomes when the tree canopy is reduced, and it apparently also increases following creeping ground fire. Its windblown seed provides long-distance dispersal and probably germinates on bare soil. In this manner, small amounts of *Aster* can establish following stand-destroying wildfire or clearcutting with scarification. The *Aster* can then increase vegetatively to form extensive colonies, which persist on well-timbered sites. For this reason, *Aster conspicuus* is considered successionally similar to *Carex geyeri* as an indicator of late seral stages (fig. 19).

The CAGE l.g. consists of three layer types, two of which were sampled (fig. 20). Four of the stands experienced partial loss of the tree canopy from wildfire about 50 to 70 years ago. The remaining stand was clearcut and lightly scarified 11 years ago. None of these sites were being grazed by livestock.

CALAMAGROSTIS RUBESCENS LAYER GROUP (CARU L.G.)

Calamagrostis rubescens is a rhizomatous grass that can maintain high coverages under moderate shade as well as in openings. With increased sunlight, *Calamagrostis* can acquire new vigor and easily dominate the herb layer. Its spring-summer forage value is considered high for bear and elk (appendix C).

Arnica cordifolia is a shade-tolerant rhizomatous forb that can develop substantial coverages in clearcuts or open stands of timber. But, on most ABGR/VAGL sites, *Arnica* displays low coverages beneath a shrub or tree canopy and persists in moderate shade more successfully than most other forbs. It shows little ability to increase from seed following any type of disturbance and, like most wind-dispersed species, does not store its seed in the soil (Kramer 1984). *Arnica* increases most effectively from residual plants following partial cutting without scarification and has moderate forage value for deer and elk (appendix C).

Pedicularis racemosa is not a common forb in ABGR/VAGL but occasionally is well represented beneath stands partially destroyed by wildfire. Although nonrhizomatous, *P. racemosa* can persist beneath a moderately dense tree canopy. It apparently does not store its seed in the soil (Kramer 1984), and its seedbed requirements are unknown. It has moderate forage value for deer and elk (appendix C).

The CARU l.g. consists of two layer types, both of which were sampled (fig. 20). The CARU-CARU layer type is more common than any other herb layer type in ABGR/VAGL. CARU-THOC is relatively scarce. In most cases, these two layer types resulted from successional advance. It is not likely that they can be generated directly from site treatment even though several sites had been clearcut. In these cases, site treatment did not effectively alter the herb layer composition and allowed a preexisting CARU layer type to remain intact. All but two of the sampled sites were receiving little or no livestock use; light use by deer was evident in some stands.

THALICTRUM OCCIDENTALE LAYER GROUP (THOC L.G.)

Thalictrum occidentale is a shade-tolerant rhizomatous forb that can produce high coverages in old-growth stands. No other species in the herb layer appears capable of replacing *Thalictrum* without the aid of disturbance. The *Thalictrum* coverage can be reduced by moderate scarification, burning, and in some cases, just removal of the tree canopy. *Thalictrum* does not appear capable of storing its seed in the soil (Kramer 1984).

Actaea rubra is a shade-tolerant forb that can increase vegetatively and form small clumps. In ABGR/VAGL, it is restricted to the most moist portions of the habitat type and indicates sites well suited for *Picea* and *Alnus*. Occasionally, *Actaea* becomes well represented where all other forbs are sparse and so is treated as an alternate climax indicator (fig. 19).

In ABGR/VAGL, the THOC-THOC layer type occurs throughout most of the habitat type but may be absent on the dry extremes. In these cases, the CARU-CARU layer type would be the successional endpoint. Being climax, THOC-THOC can only be attained through successional advance of younger layer types. It may also remain intact following creeping ground fire that does not destroy the *Thalictrum* rhizomes. Most of the sampled stands contained little or no sign of livestock use; occasional deer use was evident.

MANAGEMENT IMPLICATIONS

Management implications of the herbaceous layer focus on relative forage values to big game and livestock. A relative index to forage preferences by herb layer type (table 19) was developed by the same method used for the shrub layer (table 8). The palatability ratings given for each species in appendix C were multiplied by the percentage constancy and average canopy coverage shown for that species in a given layer type. This step was repeated for all species in that layer type, and the results were summed to give a relative forage index, which was then reduced to index classes (table 19). Some of the advantages and shortcomings of using this approach were previously noted (see shrub layer management implications). Range and wildlife managers who have better palatability ratings for a local area can easily recalculate the forage preference indexes from appendix C. Users of table 19 should consider the often small sample size of some layer types and possible revision of index values with increased sampling. As more data become available, these forage preference indexes can provide general guidelines to grazing potential for specific management objectives. When both herb and shrub layer types are known for a given site, the index values assigned in table 19 can be added to those in table 8 to give a total forage index for that site.

Table 19—Relative index classes to big-game and livestock forage preferences by herb layer type in ABGR/VAGL h.t.[1]

Layer group layer type	No. of stands	Deer SU[2]	Deer W	Elk SU	Elk W	Cattle SU	Sheep SU	Black bear SP	Black bear SU	Black bear F
Carex rossii										
CARO-CARO	12	[3]1	1	1	1	1	1	1	1	0
CARO-CAMI	5	2	1	2	1	1	2	1	1	0
CARO-FRVE	3	2	1	1	1	1	2	1	1	0
CARO-CAGE	1	1	1	2	1	2	2	2	1	1
CARO-CARU	1	1	1	2	1	2	2	1	1	0
CARO-THOC	1	1	1	2	1	1	2	1	1	0
Epilobium angustifolium										
EPAN-EPAN	1	1	0	1	0	0	1	0	0	0
EPAN-CAGE	2	2	1	2	1	2	2	1	1	0
EPAN-CARU	2	2	2	5	2	4	3	3	2	1
EPAN-THOC	1	1	0	2	0	1	1	0	0	0
Castilleja miniata										
CAMI-CAMI	1	1	0	1	0	1	1	0	0	0
CAMI-FRVE	2	2	1	2	1	2	2	2	1	1
CAMI-CAGE	1	1	1	2	1	1	1	1	1	0
CAMI-CARU	2	2	2	4	3	4	3	3	2	1
Fragaria vesca										
FRVE-FRVE	1	2	2	1	2	1	2	1	2	1
FRVE-CARU	3	2	2	2	2	2	2	2	2	1
Carex geyeri										
CAGE-CAGE	2	1	1	1	1	1	1	1	0	0
CAGE-CARU	3	1	1	2	2	2	1	2	1	1
Calamagrostis rubescens										
CARU-CARU	14	1	1	2	1	2	2	2	1	1
CARU-THOC	1	2	1	2	1	2	2	1	1	0
Thalictrum occidentalis										
THOC-THOC	5	1	1	2	1	1	1	0	0	0

[1]Based on palatability ratings by Kufeld (1973), Kufeld and others (1973), USDA-FS (n.d.), and Beecham (1981).
[2]SP = spring (March, April, May); SU = summer (June, July, August); F = fall (September, October, November); W = winter (December, January, February).
[3]Code to index classes: 0 = 0-50; 1 = 51-150; 2 = 151-250; 3 = 251-350; 4 = 351-450; 5 = 451-550; 6 = 551-650; 7 = 651-750.

Deer—In contrast to the shrub layer, herb layer forage values for deer are low to nil in all seral conditions sampled to date (table 19). These values reflect the combined effects of relatively low herb layer canopy coverages on these cool sites and the relatively low palatability of most herb layer species in ABGR/VAGL (appendix C). But certain shrub layer types on these same sites ranked moderate to high for summer deer herds (table 8).

Elk—Herb layer forage values for elk are mostly low, but a few layer types have moderate value. The highest values to date are in the EPAN-CARU and CAMI-CARU herb layer types (table 19). These values hinge mainly on the high coverages and high palatability of *Calamagrostis rubescens* (appendix C). Following tree removal, the *Calamagrostis* can easily attain high coverages in early to midseral stages but may decline somewhat under the denser tree canopies associated with late seral to near climax conditions.

Cattle—Herb layer forage values for cattle are mostly low throughout ABGR/VAGL succession (table 19). Only the EPAN-CARU and CAMI-CARU layer types, which ranked highest for elk, have moderate value for cattle. It is noteworthy that corresponding values for summer elk equal or exceed those for cattle in all herb layer types. The same is true of the shrub layer types where forage values for cattle are generally low while those for elk may be moderate to high (table 8).

Sheep—Herb layer forage values for sheep in ABGR/VAGL are similar to those for cattle, with the highest values again being in the EPAN-CARU and CAMI-CARU layer types. The sheep, however, have somewhat higher forage values than cattle in the shrub layer suggesting that ABGR/VAGL sites are better suited for sheep than for cattle.

Black Bear—The pattern of forage values for bear in ABGR/VAGL herb layer types is generally low to occasionally moderate. The highest forage values for black bear result from high coverages of *Calamagrostis* and occur in the CAMI-CARU and EPAN-CARU herb layer types during the spring (table 19). These two herb layer types are most easily achieved by removing the tree canopy of stands containing *Calamagrostis* and lightly scarifying the site. On some sites, prescribed surface fires designed to stimulate the *Calamagrostis* and eliminate small *Abies* and *Pseudotsuga* as well as the logging slash, may also contribute to these two herb layer types.

Pocket Gophers—The relationships between pocket gopher occurrence and silvicultural activities were discussed in the tree layer section. In general, scarification without burning resulted in the most gopher activity (table 3). The scarification generally produces early seral herb layer types which apparently stimulate gopher populations. The scarification producing these herb layers can result from either machinery or heavy livestock use and may account for the observed correlation between heavy grazing and high gopher activity (Buechner 1942). The relationship between gopher activity and early seral herb layers created by scarification without burning was also found in other habitat types (Steele and Geier-Hayes 1985, 1986). In contrast, other disturbances, such as broadcast burning, generally result in either a depauperate herb layer, often due to rapid shrub development, or a more successionally advanced herb layer type. These conditions often result in less gopher activity.

In summarizing studies of pocket gophers, Teipner and others (1983) suggest that plant species composition and abundance are the main regulators of gopher density. More specifically, Andersen and MacMahon (1981) correlated gopher population decline in a spruce-fir forest with decreasing palatable vegetation due to advancing successional stages. Succession in ABGR/VAGL, especially the herbaceous layer, also appears related to gopher activity. Here, occurrence and number of gopher mounds were tallied in either a 538-ft^2 (50-m^2) or 4,037-ft^2 (375-m^2) circular plot and summarized according to herb layer type (fig. 21). Because not all gopher activity results in new mounds, the number of mounds per acre may at times be a poor reflection of gopher density but should indicate relative activity between sites in the upper soil profile where feeding occurs.

Although pocket gophers are seldom a serious problem in ABGR/VAGL, figure 21 shows that gopher activity is highest in the CARO l.g. Herb layer types in this group are generated mainly from scarification without burning. Except for two sample plots, gopher activity in the more advanced herb layer types was virtually nil (fig. 21). This trend is similar to that found by Andersen and MacMahon (1981) and further suggests that certain early seral species

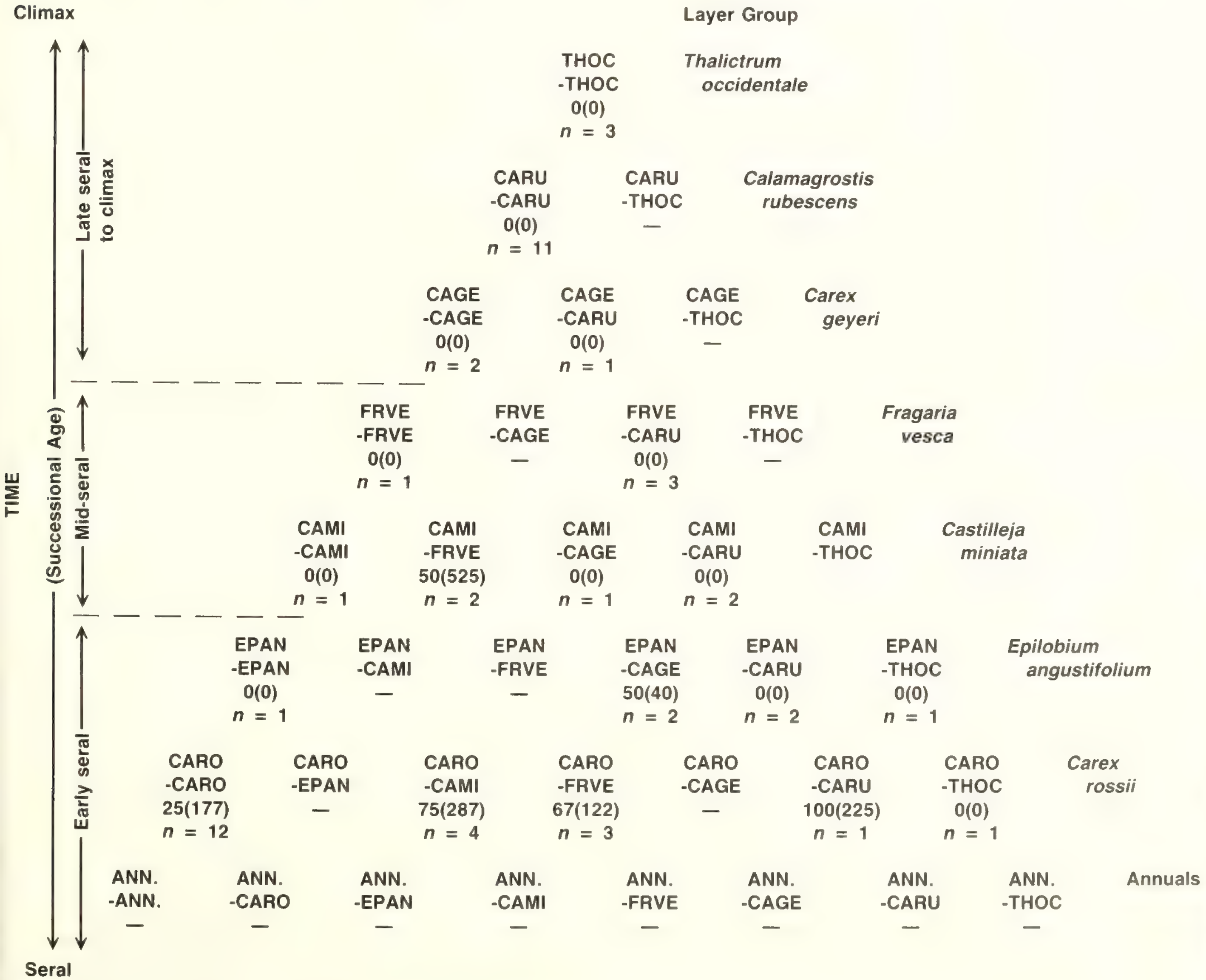


Figure 21—Constancy and average number per acre of pocket gopher mounds in various herb layer types (*n* = number of samples).

may provide the greatest benefit to gophers. In laboratory feeding tests, gophers gained or maintained body weight on exclusive diets of both *Taraxacum* and *Erigeron*, and generally maintained their weight on *Bromus carinatus* and *Bromus inermis* (Tietjen and others 1967). In ABGR/VAGL, all of these taxa would be early seral species similar to *Carex rossii*. In contrast, gophers died on exclusive diets of *Geranium* (Tietjen and others 1967) and *Epilobium angustifolium* (Andersen and MacMahon 1985), both of which have greater successional amplitude than *Carex rossii*. Although inconclusive at this point and not applicable to all species, additional feeding tests using a wider variety of plant species may substantiate this trend.

SUMMARY OF HERB LAYER SECTION

The herb layer classification consists of eight layer groups and 36 layer types. It contains more variability than the tree or shrub layer classification and may eventually require more refinement.

The annuals layer group can result from either burning or scarification. It is usually of short duration but can be maintained by intense livestock use. The CARO l.g. usually results from thorough scarification without burning and can be maintained by heavy livestock use. The EPAN l.g. usually results from burning or otherwise exposing deep loose soil. In ABGR/VAGL these two layer groups reflect early seral stages.

The CAMI l.g. usually results from successional advance of the CARO l.g. and occurs mainly on the drier portions of ABGR/VAGL. The FRVE l.g. also results mainly from successional advance but occurs throughout ABGR/VAGL. Both of these herb layer groups are considered midseral stages in ABGR/VAGL.

The CAGE, CARU, and THOC l.g.'s usually result from successional advance but may also appear in cutover areas where the site received little or no disturbance. All of these are considered late seral to climax layer groups.

Forage value of the herb layer for big game and livestock is mostly low throughout ABGR/VAGL succession. Only the CAMI-CARU and EPAN-CARU l.t.'s had moderate value, in this case for summer elk herds and spring bear.

Pocket gophers are generally not a serious problem in ABGR/VAGL. Clearcutting followed by both scarification (without burning) and repeated grazing, however, is likely to result in high gopher activity.

REFERENCES

Alexander, R. R.; Shepperd, W. D.; Edminster, C. B. Yield tables for managed stands of spruce-fir in the central Rocky Mountains. Research Paper RM-134. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1975. 20 p.

Alexander, R. R. Site index for Engelmann spruce in the central Rocky Mountains. Research Paper RM-32. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1967. 7 p.

Andersen, D. C.; MacMahon, J. A. Population dynamics and bioenergetics of a fossorial herbivore, *Thomomys talpoides* (Rodentia:Geomyidae), in a spruce-fir sere. Ecological Monographs. 51: 179-202; 1981.

Andersen, D. C.; MacMahon, J. A. Plant succession following the Mount St. Helens volcanic eruption: facilitation by a burrowing rodent, *Thomomys talpoides*. American Midland Naturalist. 114: 62-69; 1985.

Baker, F. S. Reproduction of ponderosa pine at low elevations in the Sierra Nevadas. Journal of Forestry. 40: 401-404; 1942.

Bazzaz, F. A. The physiological ecology of plant succession. Annual Review of Ecology and Systematics. 10: 351-371; 1979.

Beecham, J. Black bear food preference ratings. 1981. Report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Bernsten, C. M. Seedling distribution on a spruce-hemlock clearcut. Research Note PNW-119. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1955. 7 p.

Boe, K. N. Regeneration and slash disposal in lodgepole pine clearcuttings. Northwest Science. 30: 1-11; 1956.

Boyd, R. J.; Deitschman, G. H. Site preparation aids natural regeneration in western larch-Engelmann spruce strip clearcuttings. Research Paper INT-64. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1969. 10 p.

Bray, J. R.; Curtis, J. T. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs. 27: 325-349; 1957.

Brickell, J. R. Equations and computer subroutines for estimating site quality of eight Rocky Mountain species. Research Paper INT-75. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1970. 22 p.

Brinkman, K. A. *Salix* L. In: Seeds of woody plants in the United States. Agriculture Handbook 450. Washington, DC: U.S. Department of Agriculture; 1974: 746-750.

Bruna, J. A. [Personal communication.] 1984. Forester, Idaho Department of Lands, Boise, ID.

Buechner, H. K. Interrelationships between the pocket gopher and land use. Journal of Mammalogy. 23(3): 346-348; 1942.

Cochran, P. H. Natural regeneration of lodgepole pine in south central Oregon. Research Note PNW-204. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1953. 18 p.

Dahms, W. G. Dispersal of lodgepole pine seed into clearcut patches. Research Note PNW-3. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1963. 7 p.

Daniel, T. W.; Schmidt, J. Lethal and nonlethal effects of the organic horizons of forested soils on the germination of seeds from several associated conifer species of the Rocky Mountains. Canadian Journal of Forest Research. 2: 179-184; 1971.

Daubenmire, R. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs. 22: 301-330; 1952.

Daubenmire, R. A canopy-coverage method of vegetational analysis. Northwest Science. 33: 43-66; 1959.

Daubenmire, R.; Daubenmire, J. B. Forest vegetation of eastern Washington and northern Idaho. Technical Bulletin 60. Pullman, WA: Washington Agricultural Experiment Station; 1968. 104 p.

Day, R. J. Spruce seedling mortality caused by adverse summer microclimate in the Rocky Mountains. Publication 1003. Calgary, AB: Canadian Forestry Branch; 1963. 36 p.

Day, R. J. The microenvironments occupied by spruce and fir regeneration in the Rocky Mountains. Publication 1037. Calgary, AB: Canadian Forestry Branch; 1964. 25 p.

Day, R. J.; Duffy, P. J. B. Regeneration after logging in the Crowsnest Forest. Publication 1007. Calgary, AB: Department of Forestry; 1963. 32 p.

del Moral, R.; Cates, R. G. Allelopathic potential of the dominant vegetation of western Washington. Ecology. 52: 1030-1037; 1971.

Dingle, R. W. Pocket gophers as a cause of mortality in eastern Washington pine plantations. Journal of Forestry. 54(12): 832-835; 1956.

Fiedler, C. E.; McCaughey, W. W.; Schmidt, W. C. Natural regeneration in Intermountain spruce-fir forests —a gradual process. Research Paper INT-343. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 12 p.

Foiles, M. W.; Curtis, J. D. Regeneration of ponderosa pine in the Northern Rocky Mountain—Intermountain Region. Research Paper INT-145. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 44 p.

Geier-Hayes, K. Occurrence of conifer seedlings and their microenvironments in disturbed areas in central Idaho. Moscow, ID: University of Idaho; 1985. 99 p. M.S. thesis.

Haig, I. T.; Davis, K. D.; Weidman, R. W. Natural regeneration in the western white pine type. Technical Bulletin 767. Washington, DC: U.S. Department of Agriculture, Forest Service; 1941. 99 p.

Hann, W. J. A taxonomy for classification of seral vegetation of selected habitat types in western Montana. Moscow, ID: University of Idaho; 1982. 235 p. Ph.D. dissertation.

Harper, J. L. Population biology of plants. San Francisco: Academic Press; 1977. 892 p.

Harrington, M. G.; Kelsey, R. G. Influence of some environmental factors on initial establishment and growth of ponderosa pine seedlings. Research Paper INT-230. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 26 p.

Harvey, A. E. The importance of residual organic debris on site preparation and amelioration for reforestation. In: Baumgartner, David M., ed. Site preparation and fuels management on steep terrain: Symposium proceedings; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension; 1982: 75-85.

Heidmann, L. J.; Johnsen, T. N.; Cole, Q. W.; Cullum, G. Establishing natural regeneration of ponderosa pine in central Arizona. Journal of Forestry. 80: 77-79; 1982.

Hitchcock, C. L.; Cronquist, A. Flora of the Pacific Northwest. Seattle, WA: University of Washington Press; 1973. 730 p.

Horsley, S. B. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Canadian Journal of Forest Research. 7: 205-216; 1977.

Huschle, G.; Hironaka, M. Classification and ordination of seral plant communities. Journal of Range Management. 33(3): 179-182; 1980.

Johnson, C. G.; Simon, S. A. Plant associations of Hells Canyon National Recreation Area. Wallowa-Whitman National Forest Review Draft. Baker, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1985. 258 p.

Kramer, N. B. Mature forest seed banks on three habitat types in central Idaho. Moscow, ID: University of Idaho; 1984. 107 p. M.S. thesis.

Kufeld, R. C. Foods eaten by the Rocky Mountain elk. Journal of Range Management. 26: 106-113; 1973.

Kufeld, R. C.; Wallmo, O. C.; Feddema, C. Foods of the Rocky Mountain mule deer. Research Paper RM-111. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1973. 31 p.

Lanner, R. M. Avian seed dispersal as a factor in the ecology and evolution of limber and whitebark pines. In: Dancik, B.; Higginbotham, K., ed. 6th North American forest biology workshop: Symposium proceedings; 1980 August 11-13; Edmonton, AB. Edmonton, AB: University of Alberta; 1980: 15-48.

Layser, E. F. Vegetative classification: its application to forestry in the northern Rocky Mountains. Journal of Forestry. 72: 354-357; 1974.

Lotan, J. E. Regeneration of lodgepole pine: a study of slash disposal and cone opening. Research Note INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1964. 4 p.

Lynch, D. W. Effects of stocking on site measurements and yield of second-growth ponderosa pine in the Inland Empire. Research Paper 56. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1958. 36 p.

Martin, A.; Zim, H. S.; Nelson, A. L. American wildlife and plants: a guide to wildlife food habits: the use of trees, shrubs, weeds, and herbs by birds and mammals of the United States. New York: Dover Publications; 1951. 500 p.

Medin, D. E. [Personal communication.] 1984. Research Wildlife Biologist, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

Megahan, W. F.; Steele, R. An approach for predicting snow damage to ponderosa pine plantations. Forest Science. 33(2): 485-503; 1987.

McConkie, A. R.; Mowat, E. L. A preliminary study of factors affecting establishment of ponderosa pine and

Douglas-fir seedlings in central Idaho. 1936. Interim report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID. 66 p.

Miller, M. Response of blue huckleberry to prescribed fires in a western Montana larch-fir forest. Research Paper INT-188. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 33 p.

Minore, D. Comparative autecological characteristics of northwestern tree species—a literature review. General Technical Report PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 72 p.

Minore, D. *Vaccinium membranaceum* berry production seven years after treatment to reduce overstory tree canopies. Northwest Science. 58(3): 208-212; 1984.

Mitchell, W. M. On the ecology of Sitka alder in the subalpine zone of south-central Alaska. In: Trappe, J. M.; Franklin, J. F.; Tarrant, R. F.; Hansen, G. M., eds. Biology of alder: Symposium proceedings; 1967 April 14-15; Pullman, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968: 45-56.

Monserud, R. A. Applying height growth and site index curves for inland Douglas-fir. Research Paper INT-347. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 22 p.

Moore, A. W. The pocket gopher in relation to yellow pine reproduction. Journal of Mammalogy. 24(2): 271-272; 1943.

Mueller-Dombois, D.; Ellenberg, H. Aims and methods of vegetation ecology. New York: John Wiley and Sons; 1974. 547 p.

Oliver, W. W. Snow bending of sugar pine and ponderosa pine seedlings. . .injury not permanent. Research Note PSW-225. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1970. 3 p.

Petersen, T. D.; Newton, M. Growth of Douglas-fir following control of snowbrush and herbaceous vegetation in Oregon. Down to Earth. 41: 21-25; 1985.

Pfister, R. D. Forest habitat type classification in the western United States. In: Grey, D. C.; Schonau, A. P. G.; Schotz, L. S., eds. Symposium on site and productivity of fast growing plantations: IUFRO proceedings; 1984 April 30-May 11; Pretoria and Pietermaritzburg, South Africa. Pretoria, South Africa: South African Forest Research Institute; 1984: 149-162.

Pfister, R. D.; Arno, S. F. Classifying forest habitat types based on potential climax vegetation. Forest Science. 26: 52-70; 1980.

Pfister, R. D.; Kovalchik, B.; Arno, S. F.; Presby, R. C. Forest habitat types of Montana. General Technical Report INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 174 p.

Poore, M. E. D. The method of successive approximation in descriptive ecology. Advances in Ecological Research. 1: 35-68; 1962.

Reed, M. J. *Ceanothus* L. In: Seeds of woody plants in the United States. Agriculture Handbook 450. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974: 284-290.

Rehfeldt, G. E. Components of adaptive variation in *Pinus contorta* from the Inland Northwest. Research Paper INT-375. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987. 11 p.

Rehfeldt, G. E.; Cox, R. G. Genetic variation in a provenance test of 16-year-old ponderosa pine. Research Note INT-201. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 7 p.

Richens, V. B. An evaluation of control on the Wasatch pocket gopher. Journal of Wildlife Management. 29(3): 413-425; 1965.

Roe, A. L.; Alexander, R. R.; Andrews, M. D. Engelmann spruce regeneration practices in the Rocky Mountains. Production Research Report 115. Washington, DC: U.S. Department of Agriculture, Forest Service; 1970. 32 p.

Shearer, R. C.; Schmidt, W. C. Natural regeneration in ponderosa pine forests of western Montana. Research Paper INT-86. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1970. 19 p.

Schmidt, W. C. Seedbed treatments influence seedling development in western larch forests. Research Note INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1969. 7 p.

Stage, A. R. Site index curves for grand fir in the Inland Empire. Research Note INT-71. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1959. 4 p.

Steele, R. An approach to classifying seral vegetation within habitat types. Northwest Science. 58: 29-39; 1984.

Steele, R.; Pfister, R. D.; Ryker, R. A.; Kittams, J. A. Forest habitat types of central Idaho. General Technical Report INT-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 138 p.

Steele, R.; Geier-Hayes, K. The grand fir/blue huckleberry habitat type: succession and management. Preliminary draft. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory; 1982. 54 p.

Steele, R.; Geier-Hayes, K. The Douglas-fir/ninebark habitat type in central Idaho: succession and management. Preliminary draft. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory; 1983. 83 p.

Steele, R.; Geier-Hayes, K. The Douglas-fir/pinegrass habitat type in central Idaho: succession and management. Preliminary draft. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory; 1984. 124 p.

Steele, R.; Geier-Hayes, K. The grand fir/mountain maple habitat type in central Idaho: succession and management. Preliminary draft. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory; 1985. 118 p.

Steele, R.; Geier-Hayes, K. The Douglas-fir/white spirea habitat type in central Idaho: succession and management. Preliminary draft. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory; 1986. 96 p.

Stewart, R. E. Allelopathic potential of western bracken. Journal of Chemical Ecology. 1: 161-169; 1975.

Stickney, P. F. Data base for post-fire succession, first 6 to 9 years, in Montana larch-fir forests. General Technical Report INT-62. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 133 p.

Stickney, P. F. Data base for early post-fire succession on the Sundance Burn, northern Idaho. General Technical Report INT-189. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 121 p.

Strickler, G. S.; Edgerton, P. J. Emergent seedlings from coniferous litter and soil in eastern Oregon. Ecology. 57: 801-807; 1976.

Tackle, D. Stocking and seedbed distribution on clear-cut lodgepole pine areas in Utah. Research Note 38. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1956. 3 p.

Taylor, R. J.; Shaw, D. C. Allelopathic effects of Engelmann spruce bark stilbenes and tannin-stilbene combinations on seed germination and seedling growth of selected conifers. Canadian Journal of Botany. 61: 279-289; 1982.

Teipner, Cynthia Lea; Garton, Edward O.; Nelson, Lewis, Jr. Pocket gophers in forest ecosystems. General Technical Report INT-154. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 53 p.

Thomas, J. W., tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agriculture Handbook 553. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 512 p.

Tietjen, H. P.; Halvorson, C. H.; Hegdal, P. L.; Johnson, A. M. 2,4-D herbicide, vegetation and pocket gopher relationships: Black Mesa, Colorado. Ecology. 48(4): 634-643; 1967.

Trappe, J. M. Lodgepole pine clearcuts in northwestern Oregon. Journal of Forestry. 57: 420-423; 1959.

U.S. Department of Agriculture, Forest Service. Region 4 range management resource value ratings guide. [n.d.] Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT.

Van Horne, B. Niches of adult and juvenile deer mice (*Peromyscus maniculatus*) in seral stages of coniferous forests. Ecology. 63: 992-1003; 1982.

West, N. E. Rodent-influenced establishment of ponderosa pine and bitterbrush seedlings in central Oregon. Ecology. 49: 1009-1011; 1968.

Williamson, R. L. Results of shelterwood harvesting of Douglas-fir in the Cascades of western Oregon. Research Paper PNW-161. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1973. 13 p.

Youngberg, C. T.; Wollum, A. G.; Scott, W. *Ceanothus* in Douglas-fir clear-cuts: nitrogen accretion and impact on regeneration. In: Gordon, J. C.; Wheeler, C. T.; Perry, C. T., eds. Symbiotic nitrogen fixation in the management of temperate forests: workshop proceedings; 1979 April 2-5; Corvallis, OR. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1979: 224-233.

Youngberg, C. T.; Wollum, A. G. Nitrogen accretion in developing *Ceanothus velutinus* stands. Soil Science Society of America Journal. 40: 109-112; 1976.

Zavitkovski, J.; Woodard, E. S. Role of brush in ponderosa pine establishment. In: Hermann, R. K., ed. Regeneration of ponderosa pine. Corvallis, OR: Oregon State University, School of Forestry; 1970: 100-104.

APPENDIX A: CONSTANCY[1] AND AVERAGE CANOPY COVERAGE (PERCENT, IN PARENTHESES) OF TREES BY LAYER TYPE IN ABGR/VAGL H.T., SHOWING SIZE CLASS DISTRIBUTION AND AVERAGE BASAL AREAS

TREE LAYER GROUP		Pinus contorta											
Tree layer type		PICO - PICO				PICO - PIPO				PICO - PSME			
Size class notation		s. PICO - s. PICO				p. PICO - o.g. PIPO				p. PICO - s. PSME			
Number of stands		*n* = 7				*n* = 1				*n* = 2			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	—	3(2.0)	3(0.5)	10(10.0)	—	10(0.1)	10(3.0)	5(15.0)	5(15.0)	10(6.0)	10(9.0)
002	*Abies lasiocarpa*	—	—	—	3(0.2)	—	10(0.1)	10(0.5)	10(4.0)	—	—	—	—
006	*Larix occidentalis*	—	—	—	3(0.5)	—	—	—	—	—	5(0.1)	—	—
007	*Picea engelmannii*	—	—	—	9(1.3)	—	—	—	—	—	—	—	—
010	*Pinus contorta*	—	—	—	10(28.0)	—	10(3.0)	10(15.0)	10(3.0)	—	10(2.0)	10(15.0)	10(2.0)
013	*Pinus ponderosa*	—	—	—	4(1.3)	10(15.0)	10(3.0)	—	—	10(10.0)	—	—	—
014	*Populus tremuloides*	—	—	—	1(0.5)	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	1(3.0)	1(3.0)	6(4.1)	—	—	10(3.0)	10(3.0)	—	10(9.0)	5(15.0)	10(18.0)
Average basal area (ft^2/acre)		13				187				102			

TREE LAYER GROUP		Pinus contorta											
Tree layer type		PICO - PIEN				PICO - ABGR							
Size class notation		p. PICO - p. PIEN				p. PICO - p. ABGR				p. PICO - o.g. ABGR			
Number of stands		*n* = 1				*n* = 2				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	—	—	10(3.0)	10(9.0)	10(15.0)	10(15.0)	10(9.0)	10(38.0)	—	10(3.0)	10(3.0)
002	*Abies lasiocarpa*	—	—	10(0.1)	—	—	5(0.1)	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	—	—	—	—	—	—	—	—	—
007	*Picea engelmannii*	—	10(0.1)	10(45.0)	10(15.0)	5(15.0)	—	10(0.1)	10(0.5)	—	—	—	—
010	*Pinus contorta*	—	—	10(15.0)	—	5(15.0)	5(3.0)	10(15.0)	5(0.1)	—	10(3.0)	10(15.0)	10(0.1)
013	*Pinus ponderosa*	—	—	—	—	—	—	—	—	—	—	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	10(0.5)	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	—	—	—	—	—	—	5(0.5)	—	10(3.0)	10(0.1)	—
Average basal area (ft^2/acre)		168				238				220			

[1]Code to constancy values: + = 0 - 5%; 1 = 5 - 15%; 2 = 15 - 25%; 3 = 25 - 35%; 4 = 35 - 45%; 5 = 45 - 55%; 6 = 55 - 65%; 7 = 65 - 75%; 8 = 75 - 85%; 9 = 85 - 95%; 10 = 95 - 100%

(con.)

APPENDIX A. (Con.)[1]

TREE LAYER GROUP		Pinus contorta				Larix occidentalis							
Tree layer type		PICO - ABGR				LAOC - LAOC				LAOC - PSME			
Size class notation		m. PICO - p. ABGR				s. LAOC - s. LAOC				m. LAOC - p. PSME			
Number of stands		*n* = 1				*n* = 1				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	10(3.0)	10(15.0)	10(10.0)	—	—	—	10(0.5)	—	—	10(15.0)	10(15.0)
002	*Abies lasiocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	—	—	—	—	10(10.0)	—	10(15.0)	10(3.0)	—
007	*Picea engelmannii*	—	—	10(3.0)	10(0.5)	—	—	—	10(3.0)	—	—	—	—
010	*Pinus contorta*	—	10(15.0)	10(3.0)	10(0.5)	—	—	—	—	—	—	—	—
013	*Pinus ponderosa*	—	—	—	—	—	—	—	10(3.0)	—	—	10(15.0)	10(0.5)
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	10(0.5)	—	—	—	—
016	*Pseudotsuga menziesii*	—	10(3.0)	10(3.0)	10(0.5)	—	—	—	10(1.0)	—	—	10(20.0)	10(15.0)
Average basal area (ft²/acre)		143				3				115			

TREE LAYER GROUP		Larix occidentalis											
Tree layer type		LAOC - PSME								LAOC - PIEN			
Size class notation		o.g. LAOC - m. PSME				o.g. LAOC - o.g. PSME				m. LAOC - p. PIEN			
Number of stands		*n* = 1				*n* = 1				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	10(3.0)	—	10(15.0)	10(15.0)	10(3.0)	10(15.0)	10(3.0)	10(15.0)	10(15.0)	—	10(3.0)	10(3.0)
002	*Abies lasiocarpa*	—	—	—	—	—	—	—	10(3.0)	—	—	—	—
006	*Larix occidentalis*	10(15.0)	—	—	—	10(15.0)	—	—	—	10(3.0)	10(15.0)	—	—
007	*Picea engelmannii*	—	—	—	10(0.5)	—	—	10(0.1)	10(0.5)	—	—	10(20.0)	10(3.0)
010	*Pinus contorta*	—	—	10(3.0)	10(3.0)	—	10(0.1)	10(0.1)	—	—	—	—	—
013	*Pinus ponderosa*	—	—	—	—	—	—	—	—	—	—	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	10(15.0)	10(38.0)	10(0.1)	10(3.0)	10(38.0)	10(3.0)	10(3.0)	10(0.5)	—	—	10(15.0)	10(3.0)
Average basal area (ft²/acre)		180				234				191			

[1]Code to constancy values: + = 0 - 5% 2 = 15 - 25% 4 = 35 - 45% 6 = 55 - 65% 8 = 75 - 85% 10 = 95 - 100%
1 = 5 - 15% 3 = 25 - 35% 5 = 45 - 55% 7 = 65 - 75% 9 = 85 - 95%

(con.)

APPENDIX A. (Con.)[1]

TREE LAYER GROUP		*Larix occidentalis*								*Pinus ponderosa*			
Tree layer type		LAOC - PIEN				LAOC - ABGR				PIPO - PIPO			
Size class notation		o.g. LAOC - p. PIEN				s. LAOC - s. ABGR				s. PIPO - s. PIPO			
Number of stands		*n* = 1				*n* = 1				*n* = 14			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	—	10(15.0)	10(15.0)	10(3.0)	—	—	10(38.0)	1(0.1)	—	1(3.0)	6(0.8)
002	*Abies lasiocarpa*	—	—	10(15.0)	10(3.0)	—	—	—	—	—	—	—	1(0.1)
006	*Larix occidentalis*	10(15.0)	—	—	—	10(3.0)	—	—	10(20.0)	—	—	—	1(3.0)
007	*Picea engelmannii*	—	10(15.0)	10(20.0)	10(3.0)	—	—	—	10(3.0)	—	—	—	3(1.0)
010	*Pinus contorta*	—	—	—	—	—	—	—	—	—	—	—	4(1.0)
013	*Pinus ponderosa*	—	—	—	—	—	—	—	10(0.5)	1(0.1)	—	2(3.0)	10(27.0)
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	1(1.0)
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	3(0.5)
016	*Pseudotsuga menziesii*	—	—	—	—	—	—	—	10(5.0)	1(4.0)	—	1(10.0)	6(2.0)
Average basal area (ft^2/acre)		141				136				20			

TREE LAYER GROUP		*Pinus ponderosa*											
Tree layer type		PIPO - PIPO											
Size class notation		s. PIPO - p. PIPO				o.g. PIPO - o.g. PIPO				s. PIPO - p. PSME			
Number of stands		*n* = 3				*n* = 1				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	—	—	10(1.0)	—	—	10(3.0)	10(10.0)	—	—	10(0.1)	10(0.1)
002	*Abies lasiocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	—	—	—	10(0.1)	—	—	—	—	—
007	*Picea engelmannii*	—	—	—	7(1.0)	—	—	10(0.3)	10(0.5)	—	—	—	—
010	*Pinus contorta*	—	—	7(4.0)	3(0.5)	—	—	—	—	—	—	—	10(0.5)
013	*Pinus ponderosa*	—	—	10(30.0)	10(13.0)	10(20.0)	—	—	10(0.5)	—	—	—	10(15.0)
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	—	3(3.0)	3(0.5)	—	—	10(3.0)	10(3.0)	—	—	10(15.0)	—
Average basal area (ft^2/acre)		56				91				—			

[1]Code to constancy values: + = 0 - 5%, 1 = 5 - 15%, 2 = 15 - 25%, 3 = 25 - 35%, 4 = 35 - 45%, 5 = 45 - 55%, 6 = 55 - 65%, 7 = 65 - 75%, 8 = 75 - 85%, 9 = 85 - 95%, 10 = 95 - 100%

(con.)

APPENDIX A. (Con.)[1]

TREE LAYER GROUP		*Pinus ponderosa*											
Tree layer type		PIPO - PSME								PIPO - ABGR			
Size class notation		o.g. PIPO - m. PSME				o.g. PIPO - o.g. PSME				o.g. PIPO - p. ABGR			
Number of stands		*n* = 1				*n* = 1				*n* = 2			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	10(20.0)	10(10.0)	10(15.0)	—	—	10(10.0)	—	—	—	10(34.0)	10(9.0)
002	*Abies lasiocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	10(3.0)	—	10(3.0)	—	—	—	—	5(3.0)	5(0.1)	5(0.1)
007	*Picea engelmannii*	—	—	—	—	—	—	—	—	—	—	—	—
010	*Pinus contorta*	—	—	—	—	—	—	—	—	—	—	—	—
013	*Pinus ponderosa*	10(15.0)	—	—	—	10(15.0)	—	—	—	10(15.0)	—	5(0.1)	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	10(15.0)	10(20.0)	10(3.0)	10(62.0)	—	10(10.0)	—	10(15.0)	5(10.0)	5(20.0)	5(3.0)
Average basal area (ft²/acre)		175				192				223			

TREE LAYER GROUP		*Pseudotsuga menziesii*											
Tree layer type		PSME - PSME				PSME - ABGR							
Size class notation		p . PSME - m. PSME				p. PSME - p. ABGR				p. PSME - o.g. ABGR			
Number of stands		*n* = 1				*n* = 2				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	—	—	10(10.0)	—	10(12.0)	10(26.0)	5(15.0)	10(38.0)	—	10(3.0)	10(3.0)
002	*Abies lasiocarpa*	—	—	—	10(0.5)	—	—	—	—	—	10(15.0)	10(15.0)	10(0.1)
006	*Larix occidentalis*	—	10(3.0)	—	—	—	—	—	—	—	—	—	—
007	*Picea engelmannii*	—	10(15.0)	10(3.0)	—	—	—	5(3.0)	—	—	10(0.1)	10(3.0)	10(3.0)
010	*Pinus contorta*	—	—	—	—	—	—	—	5(0.5)	—	—	—	—
013	*Pinus ponderosa*	—	—	—	—	—	—	5(0.1)	5(0.5)	—	—	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	5(0.5)	—	—	—	—
016	*Pseudotsuga menziesii*	10(15.0)	10(20.0)	10(10.0)	—	—	—	10(15.0)	—	—	10(15.0)	10(15.0)	10(0.5)
Average basal area (ft²/acre)		242				71				162			

[1]Code to constancy values: + = 0 - 5%, 1 = 5 - 15%, 2 = 15 - 25%, 3 = 25 - 35%, 4 = 35 - 45%, 5 = 45 - 55%, 6 = 55 - 65%, 7 = 65 - 75%, 8 = 75 - 85%, 9 = 85 - 95%, 10 = 95 - 100%

(con.)

APPENDIX A. (Con.)[1]

TREE LAYER GROUP		Pseudotsuga menziesii											
Tree layer type		PSME - ABGR											
Size class notation		m. PSME - p. ABGR				o.g. PSME - s. ABGR				o.g. PSME - p. ABGR			
Number of stands		*n* = 1				*n* = 3				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	10(10.0)	10(20.0)	10(3.0)	—	7(15.0)	10(7.0)	10(24.0)	10(15.0)	10(15.0)	10(20.0)	10(10.0)
002	*Abies lasiocarpa*	—	—	—	—	—	3(3.0)	7(9.0)	7(19.0)	—	—	—	—
006	*Larix occidentalis*	—	10(0.1)	10(0.1)	—	3(0.1)	—	—	—	10(0.1)	—	—	—
007	*Picea engelmannii*	—	—	—	—	—	—	3(3.0)	3(0.1)	—	—	10(3.0)	10(0.5)
010	*Pinus contorta*	—	—	10(3.0)	—	—	—	3(0.5)	3(0.1)	—	10(3.0)	10(3.0)	—
013	*Pinus ponderosa*	—	—	—	—	3(3.0)	3(3.0)	—	—	—	—	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	10(15.0)	10(3.0)	—	10(30.0)	—	7(9.0)	3(0.5)	10(15.0)	—	—	—
Average basal area (ft^2/acre)		84				140				252			

TREE LAYER GROUP		Pseudotsuga menziesii							
Tree layer type		PSME - ABGR							
Size class notation		o.g. PSME - m. ABGR				o.g. PSME - o.g. ABGR			
Number of stands		*n* = 1				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species								
001	*Abies grandis*	10(10.0)	10(30.0)	10(15.0)	10(0.5)	10(20.0)	10(15.0)	10(10.0)	10(15.0)
002	*Abies lasiocarpa*	—	—	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	—	—	—	10(0.1)	—
007	*Picea engelmannii*	—	—	10(0.5)	10(0.5)	—	10(3.0)	10(3.0)	10(0.5)
010	*Pinus contorta*	—	10(3.0)	10(3.0)	10(0.5)	—	—	—	—
013	*Pinus ponderosa*	—	—	—	—	—	—	—	10(0.5)
014	*Populus tremuloides*	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	10(15.0)	—	10(0.5)	10(0.1)	10(15.0)	—	—	—
Average basal area (ft^2/acre)		223				128			

[1]Code to constancy values: + = 0 - 5% 2 = 15 - 25% 4 = 35 - 45% 6 = 55 - 65% 8 = 75 - 85% 10 = 95 - 100%
1 = 5 - 15% 3 = 25 - 35% 5 = 45 - 55% 7 = 65 - 75% 9 = 85 - 95%

(con.)

APPENDIX A. (Con.)[1]

TREE LAYER GROUP		Picea engelmannii											
Tree layer type		PIEN - PIEN				PIEN - ABGR							
Size class notation		o.g. PIEN - o.g. PIEN				p. PIEN - o.g. ABGR				m. PIEN - p. ABGR			
Number of stands		*n* = 1				*n* = 1				*n* = 2			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	10(15.0)	10(3.0)	10(3.0)	10(3.0)	10(45.0)	—	10(15.0)	10(3.0)	10(12.0)	10(12.0)	10(20.0)	10(15.0)
002	*Abies lasiocarpa*	—	10(0.1)	10(3.0)	10(3.0)	—	—	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	—	—	—	—	—	—	—	—	—
007	*Picea engelmannii*	10(38.0)	10(3.0)	10(0.5)	10(3.0)	10(38.0)	—	10(15.0)	10(0.5)	—	10(18.0)	10(3.0)	5(0.5)
010	*Pinus contorta*	—	—	—	—	—	—	—	—	—	—	—	—
013	*Pinus ponderosa*	—	—	—	—	—	—	—	—	—	—	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	—	—	—	—	—	—	—	—	—	—	—
Average basal area (ft^2/acre)		182				318				120			

TREE LAYER GROUP		Abies grandis											
Tree layer type		ABGR - ABGR											
Size class notation		s. ABGR - s. ABGR				s. ABGR - p. ABGR				s. ABGR - m. ABGR			
Number of stands		*n* = 1				*n* = 1				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	—	—	—	10(15.0)	10(15.0)	—	10(38.0)	10(20.0)	10(15.0)	10(20.0)	10(15.0)	10(15.0)
002	*Abies lasiocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	10(0.5)	—	—	10(3.0)	10(0.5)	—	—	—	—
007	*Picea engelmannii*	—	—	—	—	—	—	—	10(0.5)	—	—	—	—
010	*Pinus contorta*	—	—	—	—	—	—	—	—	—	—	10(3.0)	10(0.5)
013	*Pinus ponderosa*	—	—	—	10(0.5)	—	—	—	—	—	—	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	10(0.5)	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	—	—	10(0.5)	—	—	10(3.0)	—	—	—	10(0.5)	—
Average basal area (ft^2/acre)		—				194				172			

[1]Code to constancy values + = 0 - 5% 2 = 15 - 25% 4 = 35 - 45% 6 = 55 - 65% 8 = 75 - 85% 10 = 95 - 100%
1 = 5 - 15% 3 = 25 - 35% 5 = 45 - 55% 7 = 65 - 75% 9 = 85 - 95%

(con.)

APPENDIX A. (Con.)[1]

TREE LAYER GROUP		*Abies grandis*											
Tree layer type		ABGR - ABGR											
Size class notation		s. ABGR - o.g. ABGR				p. ABGR - p. ABGR				p. ABGR - o.g. ABGR			
Number of stands		*n* = 2				*n* = 2				*n* = 1			
Size classes (inches)		>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4	>18	18 - 12	12 - 4	<4
ADP No.	Species												
001	*Abies grandis*	10(29.0)	10(9.0)	10(15.0)	10(18.0)	10(12.0)	10(18.0)	10(34.0)	10(2.0)	10(38.0)	—	10(15.0)	10(3.0)
002	*Abies lasiocarpa*	—	—	—	5(4.0)	—	—	5(0.1)	—	—	—	—	—
006	*Larix occidentalis*	—	—	—	—	—	—	—	—	—	—	—	—
007	*Picea engelmannii*	—	5(3.0)	—	5(3.0)	—	—	—	—	—	—	—	—
010	*Pinus contorta*	—	5(4.0)	—	5(0.5)	—	—	5(0.5)	—	—	—	10(0.5)	—
013	*Pinus ponderosa*	5(0.1)	—	—	—	5(0.1)	—	—	—	—	10(3.0)	—	—
014	*Populus tremuloides*	—	—	—	—	—	—	—	—	—	—	—	—
015	*Populus trichocarpa*	—	—	—	—	—	—	—	—	—	—	—	—
016	*Pseudotsuga menziesii*	—	5(0.1)	—	5(3.0)	5(3.0)	5(4.0)	—	—	—	10(3.0)	10(3.0)	—
Average basal area (ft^2/acre)		179				218				355			

[1]Code to constancy values: + = 0 - 5%; 1 = 5 - 15%; 2 = 15 - 25%; 3 = 25 - 35%; 4 = 35 - 45%; 5 = 45 - 55%; 6 = 55 - 65%; 7 = 65 - 75%; 8 = 75 - 85%; 9 = 85 - 95%; 10 = 95 - 100%

APPENDIX B: PALATABILITY RATINGS, CONSTANCY,[1] AND AVERAGE CANOPY COVERAGE (PERCENT, IN PARENTHESES) OF SHRUBS BY LAYER TYPE IN ABGR/VAGL H.T.

SHRUB LAYER GROUP											Ceanothus velutinus				
Shrub layer type											CEVE -CEVE	CEVE -RIVI	CEVE -SASC	CEVE -SPBE	CEVE -VAGL
Number of stands											n = 6	n = 1	n = 1	n = 2	n = 4
ADP	Palatability ratings[2]	Deer		Elk				Black bear							
No.	Species	Summer	Winter	Summer	Winter	Cattle	Sheep	Spring	Summer	Fall					
102	*Acer glabrum*	4	6	6	6	4	4	0	0	0	2(0.5)	10(15.0)	—	—	5(0.5)
104	*Alnus sinuata*	2	2	2	2	2	2	0	0	0	2(0.5)	—	—	—	3(0.5)
105	*Amelanchier alnifolia*	4	4	6	6	4	6	2	6	6	2(0.5)	—	—	5(3.0)	8(0.5)
203	*Berberis repens*	2	4	2	4	2	4	2	2	2	2(0.5)	—	—	—	—
107	*Ceanothus velutinus*	6	4	6	6	2	2	0	0	0	10(46.3)	10(15.0)	10(15.0)	10(26.3)	10(15.0)
114	*Lonicera involucrata*	4	4	4	4	2	2	2	4	4	2(0.5)	—	—	—	—
115	*Lonicera utahensis*	2	4	6	4	2	2	2	4	4	5(7.0)	10(3.0)	10(0.5)	5(3.0)	10(9.0)
118	*Pachistima myrsinites*	4	6	4	4	2	4	0	0	0	3(1.8)	10(3.0)	—	—	3(3.0)
122	*Physocarpus malvaceus*	4	2	4	2	2	4	0	0	0	3(7.8)	10(3.0)	—	—	3(0.5)
123	*Prunus emarginata*	4	4	6	4	2	2	2	4	6	5(0.5)	—	—	—	3(0.5)
128	*Ribes cereum*	4	6	2	6	2	2	2	6	4	2(0.5)	—	—	5(0.5)	—
130	*Ribes lacustre*	4	6	6	6	2	4	2	6	4	—	—	—	5(0.5)	8(1.3)
131	*Ribes viscosissimum*	4	6	6	6	2	4	2	6	4	5(5.3)	10(15.0)	10(3.0)	5(15.0)	8(0.5)
133	*Rosa gymnocarpa*	6	4	6	4	2	4	0	0	0	—	10(0.5)	—	—	8(1.3)
161	*Rosa nutkana*	6	4	6	4	2	4	0	0	0	5(0.5)	10(0.5)	10(0.5)	5(0.5)	3(0.5)
136	*Rubus parviflorus*	4	2	6	2	2	4	2	4	2	8(3.4)	—	10(0.5)	5(0.5)	5(20.3)
#02	*Salix* spp.	4	4	4	4	2	4	0	0	0	—	—	—	—	—
137	*Salix scouleriana*	6	6	6	6	2	4	0	0	0	7(14.6)	10(3.0)	10(37.5)	5(15.0)	10(14.0)
164	*Sambucus cerulea*	0	0	6	6	4	4	2	2	2	3(1.8)	—	—	—	3(0.5)
138	*Sambucus racemosa*	0	0	6	6	4	4	2	2	2	2(0.5)	—	—	—	—
139	*Shepherdia canadensis*	2	2	2	4	2	4	2	6	4	—	—	—	—	3(0.5)
140	*Sorbus scopulina*	6	4	6	4	2	4	2	2	6	3(1.8)	10(0.5)	—	—	3(0.5)
142	*Spiraea betulifolia*	4	2	4	4	2	4	0	0	0	10(8.2)	—	—	10(26.3)	10(12.0)
143	*Symphoricarpos albus*	4	2	6	6	2	4	2	2	2	2(0.5)	—	—	—	3(3.0)
163	*Symphoricarpos oreophilus*	4	2	2	4	2	4	2	2	2	2(0.5)	10(0.5)	—	—	—
146	*Vaccinium globulare*	6	4	6	2	2	4	2	6	4	8(7.3)	10(3.0)	10(3.0)	10(9.0)	10(38.1)
Years since disturbance - average:											14	11	11	18	16
- range:											6 - 18	11	11	11 - 25	7 - 24

[1]Code to constancy values. + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Forage ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981).

(con.)

APPENDIX B. (Con.)[1]

SHRUB LAYER GROUP		Ribes viscosissimum					Salix scouleriana				
Shrub layer type		RIVI -RIVI	RIVI -SASC	RIVI -ALSI	RIVI -LOUT	RIVI -VAGL	SASC -SASC	SASC -ALSI	SASC -SPBE	SASC -LOUT	SASC -VAGL
Number of stands		*n* = 3	*n* = 1	*n* = 2	*n* = 4	*n* = 2	*n* = 3	*n* = 2	*n* = 4	*n* = 1	*n* = 8
ADP No.	Species										
102	*Acer glabrum*	—	—	—	3(0.5)	5(0.5)	—	5(0.5)	—	—	4(1.3)
104	*Alnus sinuata*	3(3.0)	—	10(50.0)	5(0.5)	—	3(0.5)	10(61.3)	—	—	6(14.7)
105	*Amelanchier alnifolia*	—	—	5(3.0)	5(1.8)	10(1.8)	7(3.0)	—	3(0.5)	10(0.5)	6(4.4)
203	*Berberis repens*	3(0.5)	—	—	—	—	3(0.5)	—	3(0.5)	—	—
107	*Ceanothus velutinus*	7(3.0)	10(3.0)	—	5(1.8)	5(3.0)	7(1.8)	5(3.0)	8(1.3)	10(3.0)	1(0.5)
114	*Lonicera involucrata*	—	—	—	—	—	3(0.5)	5(0.5)	—	—	1(3.0)
115	*Lonicera utahensis*	10(3.0)	10(3.0)	10(9.0)	10(26.3)	10(7.8)	10(5.3)	10(3.0)	8(12.8)	10(37.5)	10(11.7)
118	*Pachistima myrsinites*	3(3.0)	—	—	—	—	3(0.5)	—	—	—	1(0.5)
122	*Physocarpus malvaceus*	7(0.5)	—	5(0.5)	3(15.0)	5(0.5)	—	—	5(0.5)	10(0.5)	—
123	*Prunus emarginata*	3(0.5)	—	—	3(0.5)	—	3(0.5)	—	—	—	1(0.5)
128	*Ribes cereum*	3(0.5)	—	—	3(3.0)	5(0.5)	—	—	3(0.5)	10(0.5)	—
130	*Ribes lacustre*	3(15.0)	—	10(20.3)	5(15.0)	5(0.5)	—	5(3.0)	5(1.8)	—	4(0.5)
131	*Ribes viscosissimum*	10(38.3)	10(15.0)	10(19.0)	10(9.0)	10(15.0)	3(3.0)	10(3.0)	8(0.5)	10(0.5)	6(0.5)
133	*Rosa gymnocarpa*	10(0.5)	10(0.5)	10(0.5)	5(0.5)	10(0.5)	7(1.8)	—	5(0.5)	—	4(0.5)
161	*Rosa nutkana*	—	—	—	3(0.5)	5(3.0)	—	—	3(0.5)	10(0.5)	—
136	*Rubus parviflorus*	7(0.5)	—	10(0.5)	5(1.8)	5(0.5)	3(0.5)	5(3.0)	—	10(0.5)	4(0.5)
#02	*Salix* spp.	—	—	—	3(0.5)	—	—	—	—	—	1(0.5)
137	*Salix scouleriana*	10(2.2)	10(15.0)	10(9.0)	10(5.4)	10(7.8)	10(45.8)	10(15.0)	10(20.6)	10(15.0)	10(20.6)
164	*Sambucus cerulea*	3(0.5)	—	—	—	—	3(0.5)	—	—	10(0.5)	1(0.5)
138	*Sambucus racemosa*	3(0.5)	—	10(3.0)	8(1.3)	—	—	5(0.5)	3(0.5)	—	3(0.5)
139	*Shepherdia canadensis*	—	10(0.5)	—	3(0.5)	—	3(0.5)	10(7.8)	—	10(3.0)	8(2.2)
140	*Sorbus scopulina*	7(0.5)	—	—	5(0.5)	—	—	—	—	—	8(2.6)
142	*Spiraea betulifolia*	10(7.0)	—	10(7.8)	5(7.8)	10(1.8)	10(6.2)	5(15.0)	10(31.9)	10(3.0)	9(5.0)
143	*Symphoricarpos albus*	—	—	—	—	—	7(9.0)	—	—	—	—
163	*Symphoricarpos oreophilus*	3(0.5)	—	—	5(0.5)	—	—	—	3(0.5)	—	1(0.5)
146	*Vaccinium globulare*	10(6.2)	10(15.0)	10(7.8)	8(12.8)	10(37.5)	10(2.2)	10(19.0)	10(20.6)	10(15.0)	10(61.6)
Years since disturbance - average:		11	13	12	16	18	12	22	28	12	33
- range:		9 - 12	13	11 - 14	10 - 22	10 - 25	5 - 17	21 - 14	11 - 62	12	5 - 70

[1]Code to constancy values: + = 0- 5%; 1 = 5-15%; 2 = 15-25%; 3 = 25-35%; 4 = 35-45%; 5 = 45-55%; 6 = 55-65%; 7 = 65-75%; 8 = 75-85%; 9 = 85-95%; 10 = 95-100%

(con.)

APPENDIX B. (Con.)[1]

SHRUB LAYER GROUP		Alnus sinuata		Spiraea betulifolia			Lonicera utahensis		Vaccinium globulare
Shrub layer type		ALSI -SPBE	ALSI -VAGL	SPBE -SPBE	SPBE -LOUT	SPBE -VAGL	LOUT -LOUT	LOUT -VAGL	VAGL -VAGL
Number of stands		*n* = 1	*n* = 1	*n* = 4	*n* = 1	*n* = 5	*n* = 2	*n* = 14	*n* = 13
ADP No.	Species								
102	*Acer glabrum*	—	—	—	—	4(1.8)	5(3.0)	3(1.8)	2(2.2)
104	*Alnus sinuata*	10(15.0)	10(15.0)	—	—	—	—	1(3.0)	—
105	*Amelanchier alnifolia*	—	10(0.5)	3(0.5)	—	6(0.5)	10(1.8)	6(1.6)	5(1.9)
203	*Berberis repens*	—	—	3(0.5)	—	2(0.5)	—	1(0.5)	2(0.5)
107	*Ceanothus velutinus*	10(0.5)	—	8(1.3)	10(0.5)	2(3.0)	—	—	2(1.8)
114	*Lonicera involucrata*	—	—	3(0.5)	—	—	—	1(0.5)	—
115	*Lonicera utahensis*	10(3.0)	10(15.0)	5(0.5)	10(15.0)	8(14.6)	10(37.5)	10(15.0)	10(1.8)
118	*Pachistima myrsinites*	—	—	3(0.5)	—	—	—	4(4.9)	1(0.5)
122	*Physocarpus malvaceus*	10(0.5)	—	3(0.5)	—	—	5(15.0)	1(3.0)	2(1.3)
123	*Prunus emarginata*	—	—	—	—	—	—	1(3.0)	—
128	*Ribes cereum*	—	—	5(0.5)	—	—	—	1(0.5)	—
130	*Ribes lacustre*	10(0.5)	—	3(0.5)	—	2(0.5)	10(0.5)	1(0.5)	2(0.5)
131	*Ribes viscosissimum*	10(3.0)	—	10(1.1)	10(0.5)	2(0.5)	5(0.5)	5(1.2)	5(1.6)
133	*Rosa gymnocarpa*	10(0.5)	—	8(1.3)	10(3.0)	6(1.3)	10(1.8)	6(2.4)	6(1.4)
161	*Rosa nutkana*	—	—	3(0.5)	—	—	—	—	2(0.5)
136	*Rubus parviflorus*	10(15.0)	—	—	—	4(1.8)	10(1.8)	4(1.5)	5(1.3)
#02	*Salix* spp.	—	—	3(0.5)	10(0.5)	—	—	—	—
137	*Salix scouleriana*	10(3.0)	10(3.0)	8(2.2)	10(0.5)	4(1.8)	10(3.0)	4(2.2)	5(0.5)
164	*Sambucus cerulea*	—	—	—	—	—	—	—	—
138	*Sambucus racemosa*	—	—	3(0.5)	—	—	5(0.5)	1(0.5)	—
139	*Shepherdia canadensis*	—	10(0.5)	3(0.5)	—	6(6.2)	—	3(0.5)	1(0.5)
140	*Sorbus scopulina*	10(0.5)	10(3.0)	3(0.5)	—	6(1.3)	10(1.8)	6(0.8)	4(1.0)
142	*Spiraea betulifolia*	10(3.0)	10(3.0)	8(22.5)	10(15.0)	10(15.0)	10(0.5)	9(2.2)	7(1.6)
143	*Symphoricarpos albus*	—	—	5(7.8)	—	—	—	—	1(0.5)
163	*Symphoricarpos oreophilus*	—	—	2(0.5)	—	—	—	1(0.5)	2(1.8)
146	*Vaccinium globulare*	10(15.0)	10(85.0)	8(0.5)	10(3.0)	10(57.0)	10(15.0)	10(63.6)	10(49.0)
Years since disturbance - average:		10	70	4	9	49	52	75	85
- range:		10	70	4 - 5	9	14 - 80	15 - 90	45 - 120	14 - 170

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

APPENDIX C: PALATABILITY RATINGS, CONSTANCY,[1] AND AVERAGE PERCENTAGE CANOPY COVERAGE (PERCENT, IN PARENTHESES) OF HERBACEOUS SPECIES BY HERB LAYER TYPE IN ABGR/VAGL H.T.

HERB LAYER GROUP											*Carex rossii*					
Herb layer type											CARO -CARO	CARO -CAMI	CARO -FRVE	CARO -CAGE	CARO -CARU	CARO -THOC
Number of stands											*n* = 12	*n* = 5	*n* = 3	*n* = 1	*n* = 1	*n* = 1
	Palatability ratings[2]	Deer		Elk		Cattle	Sheep	Black bear								
ADP No.	Perennial graminoids	Summer	Winter	Summer	Winter	Summer	Summer	Spring	Summer	Fall						
336	*Agrostis scabra*	2	2	4	2	4	2	0	0	0	1(3.0)	—	—	—	—	—
303	*Bromus carinatus*	4	2	6	4	6	4	6	4	2	4(1.0)	8(4.8)	7(0.5)	—	10(0.5)	10(0.5)
304	*Bromus vulgaris*	4	2	4	4	6	4	6	4	2	—	—	3(0.5)	—	—	—
307	*Calamagrostis rubescens*	2	4	6	4	6	4	6	4	2	6(1.6)	6(1.3)	3(3.0)	10(0.5)	10(15.0)	10(0.5)
308	*Carex concinnoides*	4	4	4	4	2	6	6	4	2	3(1.3)	—	3(3.0)	—	10(0.5)	—
309	*Carex geyeri*	4	4	6	6	6	4	6	4	2	5(1.8)	4(1.8)	3(0.5)	10(15.0)	10(0.5)	10(3.0)
311	*Carex rossii*	2	2	4	2	2	4	6	4	2	10(12.8)	10(7.3)	7(7.8)	10(15.0)	10(3.0)	10(15.0)
318	*Festuca occidentalis*	4	4	4	6	6	6	0	0	0	1(0.5)	2(0.5)	7(0.5)	—	—	—
*04	*Phleum pratense*	4	4	2	6	6	6	6	4	2	1(0.5)	6(0.5)	3(0.5)	—	10(0.5)	—
	Ferns															
259	*Pteridium aquilinum*	4	0	2	0	2	4	0	0	0	—	2(15.0)	—	—	—	—
	Perennial forbs															
401	*Achillea millefolium*	2	2	2	2	2	4	0	0	0	7(0.5)	8(0.5)	10(0.5)	10(0.5)	—	—
402	*Actaea rubra*	4	0	2	0	2	2	0	0	0	—	—	—	—	—	—
405	*Anaphalis margaritacea*	2	2	2	2	2	2	0	0	0	2(0.5)	2(0.5)	7(1.8)	10(0.5)	10(0.5)	—
407	*Anemone piperi*	2	0	2	0	2	2	0	0	0	2(0.5)	2(0.5)	—	10(0.5)	—	—
414	*Antennaria microphylla*	4	2	2	2	2	4	0	0	0	1(0.5)	4(0.5)	7(0.5)	—	—	—
413	*Antennaria racemosa*	4	2	2	2	2	4	0	0	0	—	—	—	—	—	—
415	*Apocynum androsaemifolium*	2	0	2	0	2	2	0	0	0	—	—	—	—	—	—
421	*Arnica cordifolia*	4	0	4	0	2	4	0	0	0	3(1.1)	2(0.5)	3(0.5)	10(0.5)	—	10(0.5)
426	*Aster conspicuus*	2	2	4	2	4	4	0	0	0	2(0.5)	2(0.5)	7(0.5)	10(0.5)	—	10(0.5)
429	*Astragalus canadensis*	2	0	4	0	2	4	0	0	0	2(7.8)	—	—	10(0.5)	10(15.0)	—
438	*Castilleja miniata*	2	0	2	0	2	2	0	0	0	3(0.5)	2(15.0)	10(1.3)	—	10(0.5)	—
442	*Chimaphila umbellata*	0	0	0	0	0	0	0	0	0	—	—	—	—	—	—
*14	*Cirsium arvense*	2	2	2	2	2	2	0	0	0	4(0.5)	—	10(0.5)	—	—	—
596	*Cirsium scariosum*	2	2	2	2	2	2	0	0	0	—	2(0.5)	—	—	—	—
459	*Epilobium angustifolium*	4	2	6	2	2	4	0	0	0	8(0.8)	8(0.5)	3(3.0)	10(0.5)	10(0.5)	10(3.0)
889	*Epilobium watsonii*	2	0	2	0	2	2	0	0	0	1(0.5)	2(0.5)	3(0.5)	—	—	—
464	*Erythronium grandiflorum*	2	0	4	0	2	4	6	4	2	—	—	—	10(0.5)	—	—
467	*Fragaria* spp.	4	4	2	4	2	4	2	6	2	8(1.3)	10(4.4)	10(15.0)	10(0.5)	10(3.0)	10(0.5)

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Palatability ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981).

(con.)

APPENDIX C. (Con.)[1]

HERB LAYER GROUP											Carex rossii					
Herb layer type											CARO -CARO	CARO -CAMI	CARO -FRVE	CARO -CAGE	CARO -CARU	CARO -THOC
Number of stands											n = 12	n = 5	n = 3	n = 1	n = 1	n = 1
	Palatability ratings[2]	Deer		Elk		Cattle	Sheep	Black bear								
ADP No.	Perennial forbs	Summer	Winter	Summer	Winter	Summer	Summer	Spring	Summer	Fall						
471	*Galium triflorum*	2	0	2	0	2	4	4	2	2	—	2(0.5)	3(0.5)	10(0.5)	—	—
473	*Geranium viscosissimum*	4	2	6	2	2	4	0	0	0	—	2(3.0)	7(0.5)	—	—	—
621	*Geum macrophyllum*	2	0	2	0	2	4	0	0	0	—	4(1.8)	3(0.5)	—	—	—
476	*Goodyera oblongifolia*	0	0	0	0	0	0	0	0	0	—	—	—	—	—	—
483	*Hieracium albertinum*	4	2	4	2	6	6	0	0	0	2(0.5)	4(0.5)	—	10(0.5)	—	10(0.5)
484	*Hieracium albiflorum*	4	2	4	2	6	6	0	0	0	3(0.5)	2(0.5)	—	10(0.5)	—	10(0.5)
833	*Iliamna rivularis*	4	0	6	0	4	6	0	0	0	1(15.0)	2(0.5)	—	—	—	—
636	*Lathyrus nevadensis*	4	2	4	2	6	6	0	0	0	—	—	—	—	—	—
499	*Lupinus* spp.	4	2	2	4	2	4	0	0	0	—	4(26.3)	—	10(0.5)	—	—
502	*Mitella stauropetala*	2	0	2	0	2	2	0	0	0	—	—	—	10(0.5)	—	—
505	*Osmorhiza chilensis*	2	0	2	0	2	4	6	4	2	2(0.5)	4(0.5)	3(0.5)	10(0.5)	—	10(0.5)
509	*Pedicularis racemosa*	4	0	4	0	2	2	0	0	0	—	4(0.5)	—	10(0.5)	—	—
658	*Penstemon attenuatus*	4	2	2	2	2	4	0	0	0	1(15.0)	4(1.8)	7(0.5)	—	—	10(0.5)
514	*Penstemon wilcoxii*	4	2	2	2	2	4	0	0	0	6(1.6)	2(0.5)	—	10(0.5)	—	—
519	*Polemonium pulcherrimum*	4	0	4	0	2	4	0	0	0	3(1.3)	10(1.0)	7(0.5)	—	—	10(0.5)
522	*Potentilla glandulosa*	4	2	4	2	2	4	0	0	0	8(4.8)	8(12.0)	7(7.8)	10(0.5)	10(0.5)	10(3.0)
528	*Pyrola picta*	0	0	0	0	0	0	0	0	0	—	—	—	—	—	—
529	*Pyrola secunda*	0	0	0	0	0	0	0	0	0	1(0.5)	—	—	—	—	—
675	*Rudbeckia occidentalis*	4	2	2	2	2	4	0	0	0	—	2(0.5)	3(15.0)	—	—	10(0.5)
*06	*Rumex acetosella*	2	0	2	0	2	2	0	0	0	2(0.5)	4(1.8)	—	—	—	—
542	*Smilacina racemosa*	6	2	4	2	2	4	6	4	2	3(0.5)	—	3(0.5)	10(0.5)	—	—
547	*Thalictrum occidentale*	4	2	6	2	2	4	0	0	0	5(0.9)	6(10.2)	10(2.2)	10(3.0)	—	10(15.0)
562	*Thermopsis montana*	2	2	2	2	2	2	6	2	2	—	2(15.0)	—	10(0.5)	—	—
*09	*Tragopogon dubius*	4	2	4	4	4	4	0	0	0	3(0.5)	—	—	—	10(0.5)	—
560	*Trillium ovatum*	0	0	0	0	0	0	4	4	2	3(0.5)	6(0.5)	—	10(0.5)	10(0.5)	—
551	*Valeriana sitchensis*	4	0	6	0	2	4	0	0	0	2(0.5)	4(0.5)	—	10(0.5)	10(0.5)	—
554	*Viola adunca*	2	0	2	0	4	6	0	0	0	1(0.5)	—	—	10(0.5)	—	—
557	*Viola orbiculata*	2	0	2	0	2	4	0	0	0	1(0.5)	—	—	—	—	—

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Palatability ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981).

(con.)

APPENDIX C. (Con.)[1]

HERB LAYER GROUP											Carex rossii					
Herb layer type											CARO -CARO	CARO -CAMI	CARO -FRVE	CARO -CAGE	CARO -CARU	CARO -THOC
Number of stands											*n* = 12	*n* = 5	*n* = 3	*n* = 1	*n* = 1	*n* = 1
	Palatability ratings[2]	Deer		Elk		Cattle	Sheep	Black bear								
ADP No.	Annuals, biennials, and short-lived perennials	Summer	Winter	Summer	Winter	Summer	Summer	Spring	Summer	Fall						
#09	*Arabis* spp.	2	0	2	0	2	2	0	0	0	1(0.5)	2(0.5)	3(0.5)	—	—	—
*12	*Cirsium vulgare*	2	2	2	2	2	2	0	0	0	6(0.5)	4(0.5)	—	—	10(0.5)	10(0.5)
902	*Collinsia parviflora*	2	0	2	0	2	2	0	0	0	1(0.5)	—	—	10(0.5)	—	—
#56	*Collomia* spp.	2	0	2	0	2	2	0	0	0	1(0.5)	—	—	—	—	—
914	*Cryptantha affinis*	0	0	0	0	0	0	0	0	0	2(0.5)	—	—	—	—	—
904	*Epilobium paniculatum* (+ *E. minutum*)	2	0	2	0	2	2	0	0	0	3(3.0)	—	7(0.5)	—	—	—
930	*Gayophytum decipiens*	2	0	2	0	2	2	0	0	0	4(1.0)	2(3.0)	3(0.5)	—	—	—
886	*Gnaphalium microcephalum*	2	0	2	0	2	4	0	0	0	2(0.5)	—	3(0.5)	—	—	—
663	*Phacelia hastata*	4	2	4	2	2	4	0	0	0	3(0.5)	6(0.5)	3(0.5)	—	—	—
911	*Polygonum douglasii*	2	0	2	0	2	2	0	0	0	3(0.5)	2(0.5)	—	—	—	—
*16	*Verbascum thapsus*	2	2	2	2	2	2	0	0	0	2(0.5)	4(0.5)	—	—	10(0.5)	—
999	Bare soil										9(19.3)	10(10.2)	10(3.0)	10(15.0)	10(3.0)	10(3.0)
Years since disturbance - average											8	16	16	11	9	10
- range											3 - 18	11 - 25	11 - 22	11	9	10

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Palatability ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981).

(con.)

APPENDIX C. (Con.)[1]

HERB LAYER GROUP		Castilleja miniata				Epilobium angustifolium				Fragaria vesca		Carex geyeri		Calamagrostis rubescens		Thalictrum occidentale
Herb layer type		CAMI -CAMI	CAMI -FRVE	CAMI -CAGE	CAMI -CARU	EPAN -EPAN	EPAN -CAGE	EPAN -CARU	EPAN -THOC	FRVE -FRVE	FRVE -CARU	CAGE -CAGE	CAGE -CARU	CARU -CARU	CARU -THOC	THOC -THOC
Number of stands		*n* = 1	*n* = 2	*n* = 1	*n* = 2	*n* = 1	*n* = 2	*n* = 2	*n* = 1	*n* = 1	*n* = 3	*n* = 2	*n* = 3	*n* = 14	*n* = 1	*n* = 5
ADP No.	**Perennial graminoids**															
336	*Agrostis scabra*	—	5(15.0)	—	—	—	—	—	—	10(3.0)	3(0.3)	—	—	—	—	—
303	*Bromus carinatus*	—	5(3.0)	10(0.5)	—	10(0.5)	10(0.5)	—	10(0.5)	10(0.5)	10(0.5)	—	—	2(0.5)	—	2(0.5)
304	*Bromus vulgaris*	—	—	—	—	—	—	—	—	—	—	5(0.5)	—	2(1.3)	10(0.5)	4(0.5)
307	*Calamagrostis rubescens*	10(0.5)	5(15.0)	—	10(50.0)	—	—	10(50.0)	—	—	10(18.5)	5(3.0)	10(15.0)	7(33.6)	10(15.0)	—
308	*Carex concinnoides*	—	5(15.0)	—	5(0.5)	—	5(37.5)	—	—	—	6(0.5)	—	3(0.5)	5(1.2)	—	—
309	*Carex geyeri*	10(0.5)	—	10(15.0)	—	—	—	5(0.5)	—	10(0.5)	10(1.3)	10(7.8)	10(15.0)	5(1.6)	10(0.5)	4(0.5)
311	*Carex rossii*	10(3.0)	10(3.0)	10(0.5)	—	10(0.5)	10(1.8)	10(0.5)	10(0.5)	10(0.5)	6(0.5)	5(0.5)	3(0.5)	5(0.5)	—	8(0.5)
318	*Festuca occidentalis*	10(0.5)	10(0.5)	—	—	—	—	—	—	—	6(0.5)	—	—	0(0.5)	—	2(0.5)
*04	*Phleum pratense*	—	5(0.5)	—	—	10(0.5)	5(0.5)	—	—	—	—	—	—	—	—	2(0.5)
	Ferns															
259	*Pteridium aquilinum*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Perennial forbs															
401	*Achillea millefolium*	—	10(0.5)	10(0.5)	—	10(0.5)	5(0.5)	10(0.5)	—	10(0.5)	6(0.5)	—	3(0.5)	1(0.5)	—	—
402	*Actaea rubra*	—	—	—	—	—	—	—	10(15.0)	—	—	—	—	—	—	6(5.3)
405	*Anaphalis margaritacea*	—	—	—	—	10(0.5)	10(1.8)	—	—	—	—	—	—	—	—	—
407	*Anemone piperi*	—	5(0.5)	—	—	—	—	—	—	—	—	—	—	2(0.5)	10(0.5)	4(0.5)
414	*Antennaria microphylla*	—	—	—	—	—	5(0.5)	—	10(0.5)	10(0.5)	3(0.5)	—	—	1(0.5)	—	—
413	*Antennaria racemosa*	—	—	—	—	—	—	—	—	—	3(0.5)	—	—	0(0.5)	10(0.5)	2(0.5)
415	*Apocynum androsaemifolium*	—	—	—	—	—	—	—	—	—	3(0.5)	—	3(0.5)	0(0.5)	—	—
421	*Arnica cordifolia*	10(0.5)	10(0.5)	10(0.5)	5(15.0)	—	—	10(7.8)	10(0.5)	—	10(6.2)	—	3(0.5)	7(13.3)	10(3.0)	4(1.8)
426	*Aster conspicuus*	—	—	—	—	10(0.5)	5(15.0)	5(0.5)	—	—	6(0.5)	10(7.8)	3(3.0)	2(0.5)	10(0.5)	2(0.5)
429	*Astragalus canadensis*	—	5(0.5)	—	—	—	—	—	—	—	—	—	—	—	—	—
438	*Castilleja miniata*	10(37.5)	10(7.8)	10(15.0)	—	—	5(0.5)	5(0.5)	—	—	3(0.5)	—	—	0(0.5)	—	—
442	*Chimaphila umbellata*	—	—	—	10(1.8)	—	—	—	—	—	—	10(1.8)	3(0.5)	7(1.3)	10(0.5)	6(3.0)
*14	*Cirsium arvense*	—	5(0.5)	—	—	—	—	—	—	10(0.5)	—	—	—	0(0.5)	—	—
596	*Cirsium scariosum*	—	—	—	—	—	—	—	—	10(0.5)	—	5(0.5)	3(0.5)	—	—	—
459	*Epilobium angustifolium*	—	10(0.5)	10(0.5)	10(0.5)	10(15.0)	10(15.0)	10(15.0)	10(15.0)	—	6(1.8)	5(0.5)	6(1.8)	4(1.3)	10(3.0)	6(1.3)
889	*Epilobium watsonii*	—	5(0.5)	—	—	—	—	—	10(3.0)	—	3(0.5)	—	—	—	—	—
464	*Erythronium grandiflorum*	—	—	—	—	—	—	—	—	—	—	—	3(0.5)	1(0.5)	10(0.5)	—
467	*Fragaria* spp.	10(0.5)	10(15.0)	—	10(0.5)	10(0.5)	5(0.5)	10(0.5)	—	10(37.5)	10(15.0)	5(0.5)	3(0.5)	5(0.9)	10(0.5)	4(0.5)

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Palatability ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981)

(con.)

APPENDIX C. (Con.)[1]

HERB LAYER GROUP		*Castilleja miniata*				*Epilobium angustifolium*				*Fragaria vesca*		*Carex geyeri*		*Calamagrostis rubescens*		*Thalictrum occidentale*
Herb layer type		CAMI -CAMI	CAMI -FRVE	CAMI -CAGE	CAMI -CARU	EPAN -EPAN	EPAN -CAGE	EPAN -CARU	EPAN -THOC	FRVE -FRVE	FRVE -CARU	CAGE -CAGE	CAGE -CARU	CARU -CARU	CARU -THOC	THOC -THOC
Number of stands		*n* = 1	*n* = 2	*n* = 1	*n* = 2	*n* = 1	*n* = 2	*n* = 2	*n* = 1	*n* = 1	*n* = 3	n = 2	*n* = 3	*n* = 14	*n* = 1	*n* = 5
ADP No.	Perennial forbs															
471	*Galium triflorum*	—	5(0.5)	10(0.5)	—	—	5(0.5)	5(0.5)	10(0.5)	—	—	—	—	1(0.5)	—	6(1.3)
473	*Geranium viscosissimum*	—	—	—	—	—	—	—	—	—	—	5(0.5)	3(0.5)	—	—	—
621	*Geum macrophyllum*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
476	*Goodyera oblongifolia*	—	—	—	—	—	—	—	—	—	—	—	3(0.5)	5(0.5)	10(0.5)	6(0.5)
483	*Hieracium albertinum*	—	5(0.5)	—	—	—	5(0.5)	5(0.5)	—	—	—	—	3(0.5)	1(0.5)	—	2(0.2)
484	*Hieracium albiflorum*	10(0.5)	—	—	—	—	10(0.5)	—	—	—	3(0.5)	—	3(0.5)	3(0.5)	—	4(0.5)
833	*Iliamna rivularis*	—	—	—	—	—	5(0.5)	—	—	—	—	—	—	—	—	—
636	*Lathyrus nevadensis*	—	—	—	—	—	—	—	—	—	—	—	3(0.5)	0(0.5)	—	2(0.5)
499	*Lupinus* spp.	—	—	10(0.5)	10(15.0)	—	5(0.5)	5(0.5)	—	—	7(1.8)	5(0.5)	3(0.5)	1(0.5)	—	—
502	*Mitella stauropetala*	10(0.5)	5(0.5)	—	—	—	—	—	—	—	—	—	—	0(0.5)	—	2(0.5)
505	*Osmorhiza chilensis*	—	5(0.5)	—	—	—	—	5(0.5)	10(0.5)	—	—	5(0.5)	—	2(0.5)	—	10(0.5)
509	*Pedicularis racemosa*	—	—	—	—	—	—	—	—	—	3(0.5)	—	—	5(5.0)	—	4(0.5)
658	*Penstemon attenuatus*	—	—	—	—	—	5(0.5)	—	—	—	—	—	3(0.5)	—	—	—
514	*Penstemon wilcoxii*	—	5(0.5)	10(0.5)	—	—	5(0.5)	10(0.5)	—	—	6(0.5)	—	—	2(5.3)	—	—
519	*Polemonium pulcherrimum*	10(0.5)	5(0.5)	—	—	—	—	—	—	10(0.5)	—	5(0.5)	—	—	—	4(1.8)
522	*Potentilla glandulosa*	10(0.5)	5(0.5)	10(0.5)	—	—	—	5(0.5)	—	10(0.5)	6(0.5)	10(0.5)	—	0(0.5)	—	—
528	*Pyrola picta*	—	—	—	—	—	5(0.5)	—	—	—	—	—	—	1(0.5)	—	2(0.5)
529	*Pyrola secunda*	—	—	—	5(0.5)	10(0.5)	—	—	—	—	—	10(0.5)	—	2(0.5)	10(0.5)	8(0.5)
675	*Rudbeckia occidentalis*	—	5(0.5)	—	—	10(0.5)	—	—	—	10(3.0)	3(0.5)	—	—	—	—	—
*06	*Rumex acetosella*	—	—	—	—	10(0.5)	—	—	—	—	3(0.5)	—	—	—	—	—
542	*Smilacina racemosa*	10(0.5)	—	—	5(0.5)	—	5(0.5)	5(0.5)	10(0.5)	—	3(0.5)	5(0.5)	3(0.5)	4(0.5)	10(3.0)	6(0.5)
547	*Thalictrum occidentale*	10(3.0)	10(0.5)	10(3.0)	10(7.8)	—	—	5(3.0)	10(3.0)	—	10(1.3)	10(1.8)	6(0.5)	6(2.9)	10(15.0)	10(22.1)
562	*Thermopsis montana*	—	5(15.0)	—	—	—	—	—	—	—	—	—	—	2(0.5)	—	2(3.0)
*09	*Tragopogon dubius*	—	—	—	—	—	—	5(0.5)	—	—	—	—	—	0(0.5)	—	—
560	*Trillium ovatum*	10(0.5)	5(0.5)	—	10(0.5)	—	—	5(0.5)	—	—	3(0.5)	5(0.5)	6(0.5)	3(0.5)	—	4(0.5)
551	*Valeriana sitchensis*	10(0.5)	—	10(0.5)	5(0.5)	—	—	5(3.0)	—	—	3(0.5)	5(0.5)	3(0.5)	2(0.5)	10(3.0)	8(0.5)
554	*Viola adunca*	—	10(0.5)	10(0.5)	—	—	—	5(0.5)	—	—	6(0.5)	—	3(0.5)	1(0.5)	—	6(0.5)
557	*Viola orbiculata*	—	—	—	—	—	—	—	—	—	—	5(0.5)	—	2(1.1)	—	4(3.0)

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Palatability ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981).

(con.)

APPENDIX C. (Con.)[1]

HERB LAYER GROUP		Castilleja miniata				Epilobium angustifolium				Fragaria vesca		Carex geyeri		Calamagrostis rubescens		Thalictrum occidentale
Herb layer type		CAMI -CAMI	CAMI -FRVE	CAMI -CAGE	CAMI -CARU	EPAN -EPAN	EPAN -CAGE	EPAN -CARU	EPAN -THOC	FRVE -FRVE	FRVE -CARU	CAGE -CAGE	CAGE -CARU	CARU -CARU	CARU -THOC	THOC -THOC
Number of stands		*n* = 1	*n* = 2	*n* = 1	*n* = 2	*n* = 1	*n* = 2	*n* = 2	*n* = 1	*n* = 1	*n* = 3	n = 2	*n* = 3	*n* = 14	*n* = 1	*n* = 5
ADP No.	**Annuals, biennials, and short-lived perennials**															
#09	*Arabis* spp.	—	—	—	—	—	—	—	—	—	—	—	—	1(0.5)	—	—
*12	*Cirsium vulgare*	—	5(0.5)	—	—	—	—	—	—	—	6(0.5)	—	—	1(0.5)	—	2(0.5)
902	*Collinsia parviflora*	—	—	—	—	—	—	5(0.5)	—	—	—	—	—	—	—	—
#56	*Collomia* spp.	—	—	—	—	—	—	5(0.5)	—	—	—	—	—	1(0.5)	—	—
914	*Cryptantha affinis*	—	—	—	—	—	—	—	—	—	3(0.5)	—	—	—	—	—
904	*Epilobium paniculatum* (+ *E. minutum*)	—	5(0.5)	—	—	—	—	—	—	—	3(0.5)	—	—	1(0.5)	—	—
930	*Gayophytum decipiens*	—	5(0.5)	—	—	—	—	—	—	—	3(0.5)	—	—	1(0.5)	—	—
886	*Gnaphalium microcephalum*	—	5(0.5)	—	—	—	5(0.5)	—	—	—	—	—	—	—	—	—
663	*Phacelia hastata*	—	—	—	—	—	5(0.5)	—	—	—	3(0.5)	—	—	1(0.5)	—	—
911	*Polygonum douglasii*	—	—	—	—	—	—	—	—	—	3(0.5)	—	—	1(0.5)	—	—
*16	*Verbascum thapsus*	—	10(0.5)	—	—	—	—	—	—	—	3(0.5)	—	—	—	—	—
999	Bare soil	10(0.5)	10(3.0)	10(0.5)	—	10(3.0)	10(3.0)	5(3.0)	10(3.0)	10(3.0)	10(3.0)	5(0.5)	3(15.0)	5(6.1)	—	2(3.0)
Years since disturbance - average		25	12	22	61	6	16	12	14	14	15	70	30	44	90	75
- range		25	9 - 14	22	60 - 62	6	11 - 21	11 - 14	14	14	12 - 18	70	11 - 50	4 - 90	90	5 - 160

[1]Code to constancy values: + = 0- 5% 2 = 15-25% 4 = 35-45% 6 = 55-65% 8 = 75-85% 10 = 95-100%
1 = 5-15% 3 = 25-35% 5 = 45-55% 7 = 65-75% 9 = 85-95%

[2]Palatability ratings are taken from Kufeld and others (1973), Kufeld (1973), USDA-FS (n.d.), and Beecham (1981).

APPENDIX D: SUCCESSION CLASSIFICATION FIELD FORM FOR GRAND FIR/BLUE HUCKLEBERRY H.T.

(Code Descriptions)

Name:

Plot No.:

Location:

Date:

Livestock effects:

Fire effects:
-Age

Scarification effects:
-Age

Livestock Effects:
- 1-Light Cattle Use (palatable species stable)
- 2-Heavy Cattle Use (palatable species declining)
- 3-Light Sheep Use
- 4-Heavy Sheep Use
- 5-Trampling (soil surface exposed)
- 6-None
- 7-Other—

Fire Effects:
- 1-Stand Destroyed
- 2-Stand Partially Destroyed
- 3-Creeping Ground Fire
- 4-Hot Broadcast Burn (soil exposed by fire)
- 5-Cool Broadcast Burn (soil not exposed)
- 6-Burned Slash Piles
- 7-None
- 8-Other—

Scarification Effects:
- 1-Heavy (soil well churned)
- 2-Light (only duff removed)
- 3-Soil Scraped Away (by dozer blade)
- 4-Soil in Piles >18″ (from dozer)
- 5-None
- 6-Other—

Vegetation Coverage Class:

0-None	3-25 to 50%
T-Rare to 1%	4-50 to 75%
1-1 to 5%	5-75 to 95%
2-5 to 25%	6-95 to 100%

TREES - canopy coverage
Rate coverage by dbh classes: O.G. >18″ / M. 18-12″ / P. 12-4″ / S. 4-.1″

ADP

		O.G.	M.	P.	S.
001	*Abies grandis*				
002	*Abies lasiocarpa*				
006	*Larix occidentalis*				
007	*Picea engelmannii*				
010	*Pinus contorta*				
013	*Pinus ponderosa*				
014	*Populus tremuloides*				
016	*Pseudotsuga menziesii*				

SHRUBS - canopy coverage

ADP

- 102 *Acer glabrum*
- 104 *Alnus sinuata*
- 105 *Amelanchier alnifolia*
- 107 *Ceanothus velutinus*
- 115 *Lonicera utahensis*
- 122 *Physocarpus malvaceus*
- 123 *Prunus emarginata*
- 130 *Ribes lacustre*
- 131 *Ribes viscosissimum*
- 136 *Rubus parviflorus*
- 137 *Salix scouleriana*
- 138 *Sambucus racemosa*
- 139 *Shepherdia canadensis*
- 142 *Spiraea betulifolia*
- 143 *Symphoricarpos albus*
- 163 *Symphoricarpos oreophilus*
- 146 *Vaccinium globulare*

GRAMINOIDS

ADP

- 303 *Bromus carinatus*
- 304 *Bromus vulgaris*
- 307 *Calamagrostis rubescens*
- 308 *Carex concinnoides*
- 309 *Carex geyeri*
- 311 *Carex rossii*

PERENNIAL FORBS and FERNS

ADP

- 402 *Actaea rubra*
- 415 *Apocynum androsaemifolium*
- 421 *Arnica cordifolia*
- 426 *Aster conspicuus*
- 429 *Astragalus canadensis*
- #15 *Castilleja* spp.
- 459 *Epilobium angustifolium*
- 465 *Fragaria vesca*
- 466 *Fragaria virginiana*
- 833 *Iliamna rivularis*
- 636 *Lathyrus nevadensis*
- 499 *Lupinus* spp.
- 509 *Pedicularis racemosa*
- 658 *Penstemon attenuatus*
- 519 *Polemonium pulcherrimum*
- 522 *Potentilla glandulosa*
- 259 *Pteridium aquilinum*
- 675 *Rudbeckia occidentalis*
- 547 *Thalictrum occidentale*
- 562 *Thermopsis montana*

ANNUALS, BIENNIALS, and SHORT-LIVED PERENNIALS

ADP

- *12 *Cirsium vulgare*
- #56 *Collomia* spp.
- 914 *Cryptantha affinis*
- 904 *Epilobium paniculatum*
- 930 *Gayophytum decipiens*
- 886 *Gnaphalium microcephalum*
- 663 *Phacelia hastata*
- 911 *Polygonum douglasii*
- *16 *Verbascum thapsus*

TREE LAYER TYPE
SHRUB LAYER TYPE
HERB LAYER TYPE

Steele, Robert; Geier-Hayes, Kathleen. 1987. The grand fir/blue huckleberry habitat type in central Idaho: succession and management. Gen. Tech. Rep. INT-228. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 66 p.

A succession classification system based on 92 sampled stands is presented. A total of 21 potential tree layer types, 28 shrub layer types, and 36 herbaceous layer types are categorized by a taxonomic classification. Diagnostic keys based on indicator species provide for field identification of the types. Management implications include pocket gophers, success of planted and natural tree seedlings, big game and livestock forage preferences, and responses of major shrub and herb layer species to disturbances.

KEYWORDS: forest succession, habitat types, plant communities, forest ecology, forest management, silviculture, classification, Idaho

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho
Bozeman, Montana (in cooperation with Montana State University)
Logan, Utah (in cooperation with Utah State University)
Missoula, Montana (in cooperation with the University of Montana)
Moscow, Idaho (in cooperation with the University of Idaho)
Ogden, Utah
Provo, Utah (in cooperation with Brigham Young University)
Reno, Nevada (in cooperation with the University of Nevada)

A 13.88:INT-229, General Technical Report No. 229 is bound separately and is on the shelf just to the right of this volume.

United States Department of Agriculture

Forest Service

Intermountain Research Station

General Technical Report INT-230

Managing Wilderness Recreation Use: Common Problems and Potential Solutions

David N. Cole
Margaret E. Petersen
Robert C. Lucas

THE AUTHORS

DAVID N. COLE is research scientist with Systems for Environmental Management, P.O. Box 8868, Missoula, MT. He is working cooperatively with the Intermountain Research Station's Wilderness Management research work unit. Dr. Cole received his Ph.D. from the University of Oregon in 1977. He has written extensively about wilderness management, particularly on the ecological effects of recreation use.

MARGARET E. PETERSEN was a research forester with the Intermountain Station's Wilderness Management research work unit at the Forestry Sciences Laboratory, Missoula, MT, when this project was begun. She is now wilderness and special areas staff specialist, Pacific Northwest Region, Forest Service, U.S. Department of Agriculture, Portland, OR. She received her B.S. degree in forestry from Oklahoma State University in 1977. She received a master's degree, also in forestry, from Oregon State University in 1980. She has authored several publications dealing with wilderness recreation trends and trail register performance.

ROBERT C. LUCAS is principal research social scientist and Project Leader of the Intermountain Station's Wilderness Management research work unit at the Forestry Sciences Laboratory, Missoula. He has been with the Station since 1967. Dr. Lucas received his B.S., M.A., and Ph.D. degrees from the University of Minnesota in 1957, 1959, and 1962. He also studied at the Free University of West Berlin, Germany, and at the University of Chicago. He has authored numerous publications dealing with wilderness management.

GENERAL SUMMARY

This report summarizes information on alternative management tactics available for dealing with common wilderness recreation problems. The first section of the report describes eight basic strategies for attacking problems: reduce use of the entire wilderness, reduce use of problem areas, modify the location of use within problem areas, modify the timing of use, modify type of use and visitor behavior, modify visitor expectations, increase the resistance of the resource, and maintain or rehabilitate the resource.

The second section describes the nature of general problems resulting from recreational use of wilderness. In order of frequency, the most common problems are trail deterioration, campsite deterioration, litter, crowding, packstock impact, human waste disposal, impacts on wildlife, user conflicts, and water pollution. For each of these problems, strategies and tactics with the potential to substantially alleviate problems are listed. Tactics are specific approaches to implementing a strategy. A total of 37 tactics have been grouped according to one or another of the eight strategic purposes.

The bulk of the report describes each of these tactics. For each tactic the following topics are discussed: the purpose of the tactic; a description of how it can be used to solve specific problems; the extent of its current usage; estimated costs of implementation, both to visitors and management; likely effectiveness; comments on other considerations, particularly probable side effects; and other sources of information.

Our hope is that this report will serve as a "troubleshooting" guide. When faced with a specific problem, managers can turn to the list of primary tactics for dealing with each problem. The pros and cons of each of these can be reviewed in the section that provides detailed discussions of tactics. Selection of a tactic or, more often, a combination of tactics can then be made on the basis of information that is as complete as we could assemble.

August 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

CONTENTS

Managing Wilderness Recreation Use: Common Problems and Potential Solutions

David N. Cole
Margaret E. Petersen
Robert C. Lucas

INTRODUCTION

The Wilderness Act of 1964 established within the public lands of the United States a system of wildernesses to be managed so as to preserve both natural ecosystems and opportunities for wilderness experiences. Increased recreational use of wilderness has created many situations in which these objectives have been compromised. Where objectives are not being met, managers must seek out means of correcting these problem situations. Managers now have more than 20 years of experience in dealing with some general problems common to the entire wilderness system (Washburne and Cole 1983). Research into such problems and potential solutions to them has also accumulated over this period.

An extensive literature is now available on how to develop programs for managing recreational use. Peterson and Lime (1979) present a useful general framework for solving visitor management problems, and Lucas (1982) provides a step-by-step procedure for evaluating alternative approaches to problem solving, with particular emphasis on how to avoid unnecessary regulations. Both papers stress clearly identifying problems and carefully evaluating all potential solutions to problems. Stankey and others (1985) describe the Limits of Acceptable Change (LAC) planning system, a formalized framework for identifying problems and management responses to problems.

After more than 20 years of research and experience with managing wilderness, it seems timely to synthesize wilderness management experience, condense it, and make it readily accessible to managers currently struggling with common problems. Gilbert and others (1972) provided a list of some alternative wilderness management techniques. Hendee and others (1978) modified this table and described pros and cons of some of these techniques. But there is no detailed compilation of current knowledge about the appropriateness, effectiveness, and advantages and disadvantages of alternative management tactics. This report is an attempt to fill this gap.

PURPOSE AND ORGANIZATION

This report summarizes information useful in considering management approaches to mitigating common wilderness problems caused by recreational use. The objective of the report is to provide a "troubleshooting" guide that will aid in the selection of the most effective and efficient means of dealing with management problems. This guide shows managers faced with a specific problem—say, campsite deterioration—an array of approaches for dealing with the problem along with the pros and cons of each approach.

This report is concerned with problems caused by recreational use of wilderness. Recreation is just one of many wilderness values, but recreational use has the potential to severely compromise other values. Therefore, management of recreation is critical. Although not dealt with here, other uses of wilderness must also be managed to avoid compromise of recreation and other wilderness values.

The organization of this report is as follows: The first section discusses strategies and tactics for dealing with problems. Strategies are broad, conceptual approaches to management (Manning 1979); they attack the basic causes of problems. Tactics are the specific means or tools available for implementing a strategy; generally there are numerous tactics available to accomplish a strategy. Moreover, several strategies and tactics can, and often should, be used to deal with most problems.

The second section describes common recreation-related problems in wilderness and their primary causes. Many of the common problems are subdivided into distinct subproblems that require differing management approaches. The most important strategies and tactics for attacking the primary causes of each subproblem are listed. Managers faced with a specific problem—such as visitor conflict—can turn to the visitor conflict portion of this section to find a list of the most important tactics for dealing with this problem.

The final section (the bulk of the report) discusses the pros and cons of the 37 tactics we have identified. This represents as complete a list of alternative techniques as we could devise. We have included some tactics, such as charging entrance fees, even though current policies may prevent managers from using them. Other tactics, such as providing facilities, raise questions of appropriateness in wilderness. These issues are considered in the section that describes each tactic.

For each tactic, the following topics are discussed: the purpose of the tactic; a description of how the tactic can be used to solve specific problems; the extent of its current usage; costs of implementation, both to management and to visitors; likely effectiveness; comments on other considerations, particularly likely side effects; and sources of further information. The content of each source of information is described in brief annotations after each reference at the end of the paper.

One of our intents is to highlight the secondary effects of implementing each tactic. Most actions taken to solve a specific problem in a specific place will affect other places and may cause unexpected problems. We believe it is particularly important to consider and plan for secondary effects. There are also many situations where one tactic will be more effective if supported by other tactics. We stress situations where combinations of techniques—rather than just one technique—are likely to be particularly effective.

Our hope is that this report will provide a troubleshooting guide that managers can turn to when faced with a specific problem, or when an existing problem requires a new approach. Although personal preference must enter into such a reference, we have attempted to minimize bias by reporting the range of existing opinions where controversy exists and by soliciting comments from experienced managers, researchers, and visitors. When choosing tactics one must consider local conditions. This guide cannot identify "best" solutions that are universally applicable across diverse wilderness resources and recreational use situations. Final decisions on tactics remain the responsibility of the resource manager, as they should. But the guide can highlight the wide variety of potential solutions available and the advantages and disadvantages of each option. This should make final decisions more informed.

HOW TO USE THIS GUIDE

We suggest using the guide within the following decision-making process:

1. Clearly identify and document the problem, deciding which category of problem or subproblem it fits (see pages 4-8 for a discussion of problems).
2. Identify the strategies and tactics available for dealing with the problem or subproblem (strategies are discussed, in general, on pages 2-4; tactics are listed under each subproblem on pages 9-15).
3. Read the discussions of each of these tactics (see pages 16-54 for discussions of each tactic).
4. Decide on the set of tactics that appears most appropriate. Choose strategies that attack the primary causes of the specific problem and tactics that do not conflict with management objectives, that are realistic given the visitor use, environment, and management situation, and that minimize costs to visitors and avoid or reduce unwanted side effects.
5. Query managers who have experience with these tactics; ask how well the tactics work and pick up hints on how best to implement each tactic. Although dated, wildernesses practicing most of these tactics can be found in the appendix of Washburne and Cole (1983).
6. Prepare specific action plans to implement tactics.
7. Implement action plans.
8. Monitor how effectively the selected tactics deal with problems and modify them as necessary. This is why the documentation in step 1 is critical.

This guide is most useful in the early steps of this decision-making process. Managers must still decide on the most appropriate courses of action.

STRATEGIES FOR SOLVING PROBLEMS

A number of strategies for attacking recreation problems have been identified (Wagar 1964; Manning 1979). The term "strategy" refers to broad, general approaches to management. Although other arrangements are possible, we have grouped all 37 management tactics into eight basic strategies.

I. Reduce Use of the Entire Wilderness—This strategy is associated with the notion that each area has a carrying capacity. The idea behind this strategy is that adverse impacts on ecosystems and visitor experiences result from excessive use and can be mitigated by reducing use. With this strategy, amount of use is controlled, but distribution of use is not.

II. Reduce Use of Problem Areas—This strategy is based on recognition that in most wildernesses problems occur only in a few "problem areas"—lake basins, drainages, or other large destination areas. Use of these problem areas is reduced without necessarily reducing use of the entire wilderness. Usually some of the traffic in problem areas is moved to places with fewer problems. This strategy has been called the use-dispersal strategy.

Amount of use is only one of several factors that influence where problems occur. Other factors include the location, type, and timing of use. Consequently, there are a number of strategies for reducing per capita impact. The following four strategies involve reducing the potential impact a visitor can cause through management of visitors:

III. Modify the Location of Use Within Problem Areas—Use can be shifted to durable sites, it can be locally dispersed so that crowding and conflict are minimized, and it can be concentrated on a few sites so the area impacted is minimized. In contrast to strategy II, techniques under this strategy are implemented in order to influence how use is distributed within larger problem areas. For example, in response to problems at a popular lake basin, managers may try to either reduce use of the basin (strategy II) or control where use occurs within the basin (strategy III)—for example, on designated sites only, away from lakes, in forests rather than meadows, off of highly impacted sites, and so on.

IV. Modify the Timing of Use—The fragility of the environment varies with the time of year. In addition, certain times of the year and week are more popular than others, so crowding problems are more severe. Use can be shifted to times when it is least likely to cause impact to either the environment or other visitors.

V. Modify Type of Use and Visitor Behavior—Large parties and those with stock and pets have more potential for causing problems than small parties without stock and pets. Of even more importance, parties that do not practice low-impact behavior will cause more problems than other parties. Both type of use and behavior can be modified so that the use that does occur is less likely to cause problems.

VI. Modify Visitor Expectations—The severity of visitor experience-related problems is often influenced by the expectations users have about their likely experience

(Manning 1985). For example, backpackers tend to be less bothered by stock parties if they expect to encounter them and accept them as an appropriate type of visitor in wilderness. Similarly, encountering a large number of other parties is more acceptable if such encounters are expected. Expectations can be modified by informing visitors of appropriate wilderness uses and the types of conditions they are likely to encounter.

The final two strategies involve resource management, as opposed to visitor management:

VII. Increase the Resistance of the Resource—In addition to directing use to naturally durable sites—strategy III—managers can also artificially increase the resistance of the resource by either strengthening (hardening) it or shielding it from impact. These two options are related but involve different levels of resource manipulation. Shielding involves separating the resource from the visitors causing the problem; corduroy trails are a good example. With shielding, human modification is obvious, but the resource can remain essentially unaltered. Strengthening involves changing the resource to make it more durable; in this case natural conditions are being purposely altered by management. The most common examples of strengthening in wilderness are many of the techniques used to create a graded, compacted, erosion-resistant trail tread.

VIII. Maintain or Rehabilitate the Resource—This strategy involves treating symptoms rather than attacking the cause of problems. Impacted locations such as trails and campsites can be maintained or rehabilitated. Other problems, such as litter and human waste, can be treated by removing them from the wilderness.

Under each strategy there are a number of more specific management tactics that can be applied in attempts to solve problems (table 1). The bulk of this report (pages 16-54) discusses these 37 tactics. We have chosen to organize techniques by strategic purpose because this focuses attention on **why** the action is being taken. As is discussed in the next section, the seriousness of most problems is influenced by a small number of factors, such

Table 1—Strategies and tactics for wilderness management

I. REDUCE USE OF THE ENTIRE WILDERNESS
1. Limit number of visitors in the entire wilderness
2. Limit length of stay in the entire wilderness
3. Encourage use of other areas
4. Require certain skills and/or equipment
5. Charge a flat visitor fee
6. Make access more difficult throughout the entire wilderness

II. REDUCE USE OF PROBLEM AREAS
7. Inform potential visitors of the disadvantages of problem areas and/or advantages of alternative areas
8. Discourage or prohibit use of problem areas
9. Limit number of visitors in problem areas
10. Encourage or require a length-of-stay limit in problem areas
11. Make access to problem areas more difficult and/or improve access to alternative areas
12. Eliminate facilities or attractions in problem areas and/or improve facilities or attractions in alternative areas
13. Encourage off-trail travel
14. Establish differential skill and/or equipment requirements
15. Charge differential visitor fees

III. MODIFY THE LOCATION OF USE WITHIN PROBLEM AREAS
16. Discourage or prohibit camping and/or stock use on certain campsites and/or locations
17. Encourage or permit camping and/or stock use only on certain campsites and/or locations
18. Locate facilities on durable sites
19. Concentrate use on sites through facility design and/or information
20. Discourage or prohibit off-trail travel
21. Segregate different types of visitors

IV. MODIFY THE TIMING OF USE
22. Encourage use outside of peak use periods
23. Discourage or prohibit use when impact potential is high
24. Charge fees during periods of high use and/or high-impact potential

V. MODIFY TYPE OF USE AND VISITOR BEHAVIOR
25. Discourage or prohibit particularly damaging practices and/or equipment
26. Encourage or require certain behavior, skills, and/or equipment
27. Teach a wilderness ethic
28. Encourage or require a party size and/or stock limit
29. Discourage or prohibit stock
30. Discourage or prohibit pets
31. Discourage or prohibit overnight use

VI. MODIFY VISITOR EXPECTATIONS
32. Inform visitors about appropriate wilderness uses
33. Inform visitors about conditions they may encounter in the wilderness

VII. INCREASE THE RESISTANCE OF THE RESOURCE
34. Shield the site from impact
35. Strengthen the site

VIII. MAINTAIN OR REHABILITATE THE RESOURCE
36. Remove problems
37. Maintain or rehabilitate impacted locations

as amount, type or timing of use, and so on. Each strategy focuses management attention on one of these important influential factors. Strategies that are related to factors that have little influence on a specific problem can be ignored.

Other classifications have focused on **how** the action is accomplished. Under classifications based on method of approach, management can involve education, dissemination of information, regulation, or site manipulation. Each of these can be used to accomplish a number of strategic purposes. For example, education can be used to reduce use of the entire wilderness, to reduce use of problem areas, to modify the location of use, to modify the timing of use, to modify type of use and visitor behavior, to modify visitor expectations, and even to rehabilitate the resource (by convincing visitors to pick up other visitors' litter, for example). For purposes of identifying management approaches to specific problems, we feel it is more useful to think about techniques grouped under distinct strategies.

Within each strategy, techniques are generally arranged from most to least common. We purposely avoided attempting to arrange techniques from "best" to "worst," because what is best in one situation might be worst in another. The manager must make these decisions. We also avoided arranging them from indirect and manipulative techniques to direct and regulatory techniques (Gilbert and others 1972) because the distinction between the two is not always clear and, under certain circumstances, direct techniques may be preferable to indirect techniques. For example, some manipulative techniques involve possibly inappropriate resource modification and some persuasive techniques discriminate against conscientious visitors. These issues are raised in the discussion of each tactic (pages 16-54).

MANAGEMENT PROBLEMS

The frequency of occurrence of major problems resulting from recreational use of wilderness was evaluated in a survey of all units of the National Wilderness Preservation System in 1979 (Washburne and Cole 1983). The results apply to 110 Forest Service wildernesses, 25 Park Service wildernesses, and the 17 Fish and Wildlife Service wildernesses that received more than 500 visitor-days of use per year—152 areas in all. (As of 1986 there were 445 wildernesses.)

Deterioration of trails and campsites were the most commonly reported problems; littering and crowding were also problems in more than half the wildernesses (table 2). In an earlier survey, based on a sample of 35 wilderness managers, 80 percent of those who responded to an open-ended question about important problems mentioned trail and campsite deterioration. The only other frequently mentioned recreation-related problem was user conflict (Godin and Leonard 1979).

In addition to being a perceived problem in more wildernesses, trail and campsite deterioration were the most widespread problems within individual wildernesses. Managers were asked if problems were present in "a few places" or "many places" (Washburne and Cole 1983). The percentage of wildernesses with problems in "many places" ranged from 33 percent for campsite deterioration and 26 percent for trail deterioration to less than 2 percent for water pollution (table 2). The severity and significance of problems is another matter, however, and one for which we have no data. Problems with human waste may not be widespread, but even a few cases of disease might be considered more serious than widespread trail problems.

In the following section we describe the nature of each major problem, such as trail deterioration or crowding, and subdivide each problem into important subproblems. For example, under campsite problems, both deterioration of existing sites and proliferation of many new sites can be a problem; however, each subproblem requires a different management approach. Then we discuss the primary causes of each subproblem. This information is critical because, when selecting strategies and tactics, it is important to select those that deal with the factors that have a pronounced influence on the severity of each problem.

Finally, for each of these subproblems, we list strategies and primary tactics that can be used to deal with problems. Tactics are only listed here, often with examples. Some of these tactics are rather broad and general. The alternative of discussing very specific tactics would have produced a much longer and unwieldy list. We hope that the level of generality we have chosen is a happy medium. To provide some more specificity, however, many of the tactics under each subproblem are described in a more specific manner here than in the more generic format of table 1. For example, tactic 25, discourage or prohibit particularly damaging practices and/or equipment, is the first under strategy V, Modify Type of Use and Visitor Behavior. When listed under tactics for dealing with water pollution problems, it is described, more specifically, as discourage or prohibit pollution of water sources. Under the section on campsite deterioration problems, the same generic tactic is called discourage or prohibit particularly damaging camping practices.

Some of the tactics under different strategies are closely related, differing mostly in how a given change is brought about. For example, modifying the location of visitor use and modifying visitor behavior to avoid camping on fragile sites overlap. Modifying behavior may be how location of camping is modified. Some tactics under the same strategy

Table 2—Frequency of common wilderness problems

Problem	Percent of areas where problem: Occurs	Occurs in "many places"
Trail deterioration	76	26
Campsite deterioration	72	33
Litter	65	11
Crowding	51	13
Packstock impacts	47	18
Human waste problems	45	4
Impacts on wildlife	36	6
User conflicts	34	3
Water pollution	22	2

are also related. For example, discouraging certain practices (tactic 25) is the opposite of encouraging certain behavior (tactic 26). The two are separated because the tone of one tactic is positive, while the other is negative. Similarly, most of the tactics under strategies I and II are alternative means of reducing use; results of implementation would be similar, but the means used differ greatly.

We list only the most important tactics, which we term primary tactics, those that attack problems directly. Other tactics may help the situation but are less important and are termed secondary tactics. For example, litter problems can be reduced by convincing people not to litter; this is a primary tactic because it deals with the problem directly. Reducing use will also tend to reduce litter because there will be fewer people to leave litter, but this is considered to be a secondary tactic because it is so indirect in approach. Some secondary tactics are mentioned briefly.

Implementing any of these tactics will require selection of specific actions. We present some examples of these actions, such as providing information on maps, using wilderness ranger contacts, and so on, in the discussions of each tactic. But we do not cover every possibility nor do we tell how to prepare detailed action plans.

Finally, before implementing an action intended to mitigate a specific problem, the effects of that action on other problems and places must be considered. One action can ameliorate several problem situations. Therefore, a tactic that is of only secondary importance might be worth implementing if it produces numerous benefits. Alternatively, an action can aggravate other problems or problems in other places. The multiple benefits, costs, and likely side effects associated with implementing tactics are discussed in the section on tactics (pages 16-54).

The primary tactics useful in dealing with each problem and subproblem are summarized in the quick reference guide (table 3).

Table 3—Quick reference guide to primary strategies and tactics for each problem and subproblem

Strategies and tactics	Trails: Deterioration of managed trails	Trails: Development of undesired trails	Campsites: Excessive deterioration of campsites	Campsites: Proliferation of campsites	Litter: Litter	Crowding: Too many encounters	Crowding: Visitor conflict	Stock: Deterioration of grazing areas	Waste: Human waste	Wildlife/fish: Harassment of wildlife	Wildlife/fish: Competition with wildlife	Wildlife/fish: Attraction and feeding wildlife	Water: Contamination of water bodies
I. REDUCE USE OF THE ENTIRE WILDERNESS													
1. Limit number of visitors in the entire wilderness													
2. Limit length of stay in the entire wilderness													
3. Encourage use of other areas													
4. Require certain skills and/or equipment													
5. Charge a flat visitor fee													
6. Make access more difficult throughout the entire wilderness													
II. REDUCE USE OF PROBLEM AREAS													
7. Inform potential visitors of the disadvantages of problem areas and/or advantages of alternative areas						X		X	X	X	X		
8. Discourage or prohibit use of problem areas						X		X	X	X	X		
9. Limit number of visitors in problem areas						X		X	X	X	X		
10. Encourage or require a length-of-stay limit in problem areas						X		X	X	X	X		
11. Make access to problem areas more difficult and/or improve access to alternative areas						X		X	X	X	X		
12. Eliminate facilities or attractions in problem areas and/or improve facilities or attractions in alternative areas						X		X	X	X	X		
13. Encourage off-trail travel						X			X				
14. Establish differential skill and/or equipment requirements						X		X	X	X	X		
15. Charge differential visitor fees						X		X	X	X	X		

(con.)

Strategies and tactics	Trails: Deterioration of managed trails	Trails: Development of undesired trails	Campsites: Excessive deterioration of campsites	Campsites: Proliferation of campsites	Litter: Litter	Crowding: Too many encounters	Crowding: Visitor conflict	Stock: Deterioration of grazing areas	Waste: Human waste	Wildlife/fish: Harassment of wildlife	Wildlife/fish: Competition with wildlife	Wildlife/fish: Attraction and feeding wildlife	Water: Contamination of water bodies
III. MODIFY THE LOCATION OF USE WITHIN PROBLEM AREAS													
16. Discourage or prohibit camping and/or stock use on certain camp sites and/or locations	X		X	X		X	X	X	X	X	X	X	X
17. Encourage or permit camping and/or stock use only on certain campsites and/or locations	X		X	X		X	X	X	X	X	X	X	X
18. Locate facilities on durable sites	X	X	X			X		X	X	X	X	X	X
19. Concentrate use on sites through facility design and/or information		X	X						X				
20. Discourage or prohibit off-trail travel		X								X	X		
21. Segregate different types of visitors							X						
IV. MODIFY THE TIMING OF USE													
22. Encourage use outside of peak use periods						X							
23. Discourage or prohibit use when impact potential is high	X	X						X		X	X		
24. Charge fees during periods of high use and/or high-impact potential	X					X		X		X	X		
V. MODIFY TYPE OF USE AND VISITOR BEHAVIOR													
25. Discourage or prohibit particularly damaging practices and/or equipment		X	X	X	X	X	X	X	X	X	X	X	X
26. Encourage or require certain behavior, skills, and/or equipment		X	X	X	X	X		X	X	X	X	X	X
27. Teach a wilderness ethic		X	X	X	X	X	X	X	X	X	X	X	X
28. Encourage or require a party size and/or stock limit			X				X	X			X		

(con.)

Table 3—(Con.)

Strategies and tactics	Trails: Deterioration of managed trails	Trails: Development of undesired trails	Campsites: Excessive deterioration of campsites	Campsites: Proliferation of campsites	Litter: Litter	Crowding: Too many encounters	Crowding: Visitor conflict	Stock: Deterioration of grazing areas	Waste: Human waste	Wildlife/fish: Harassment of wildlife	Wildlife/fish: Competition with wildlife	Wildlife/fish: Attraction and feeding wildlife	Water: Contamination of water bodies
V. (con.)													
29. Discourage or prohibit stock	X		X				X	X			X		
30. Discourage or prohibit pets							X		X				
31. Discourage or prohibit overnight use			X					X		X	X		
VI. MODIFY VISITOR EXPECTATIONS													
32. Inform visitors about appropriate wilderness uses							X						
33. Inform visitors about conditions they may encounter in the wilderness							X						
VII. INCREASE THE RESISTANCE OF THE RESOURCE									X			X	
34. Shield the site from impact	X												
35. Strengthen the site	X												
VIII. MAINTAIN OR REHABILITATE THE RESOURCE													
36. Remove problems					X				X				
37. Maintain or rehabilitate impacted locations	X	X	X	X									

Trail Deterioration

The majority of the impact that occurs along trails is the purposeful result of trail construction and maintenance. Trail impacts become a problem when managed trails (those that are either agency-built or agency-sanctioned) deteriorate to the point where they are difficult to use or where unmanaged trails are developed by visitor use. Therefore, trail deterioration problems can be divided into two separate subproblems: (1) deterioration of the tread of managed trails, usually through erosion or the development of muddy stretches, and (2) development of undesired trails, such as multiple trails in meadows or networks of informal trails in popular destination areas (Cole 1987).

SUBPROBLEM 1—DETERIORATION OF MANAGED TRAILS

The incidence of erosion and muddiness problems is most strongly related to the location, design, and maintenance of the trail (Bratton and others 1979; Cole 1983a). Some locations (such as sites with erosive or water-saturated soils) and some trail designs (such as steep grades) invite deterioration. Other designs (such as use of water bars or corduroy) can compensate for a poor location. There are also situations where problem incidence is related to the amount and timing of visitor use, particularly of visitors who use stock. Stock have considerably more impact on trails than hikers (Weaver and Dale 1978). Although heavily used trails often are more heavily impacted than lightly used trails, this is not always the case, and amount of use appears to be a less influential factor than trail location, design, and maintenance (Helgath 1975; Cole 1983a). Because the most important factors influencing trail deterioration usually are location, design, and maintenance of the trail and the amount and timing of stock use, the primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit stock use on certain trails (page 32).
17. Encourage or permit stock use only on certain trails (page 34).
18. Locate trails on durable sites (page 35).

Strategy IV. Modify the Timing of Use

23. Discourage or prohibit stock use (or perhaps all use) in seasons when trails are water saturated (page 40).
24. Charge fees for stock (or perhaps all use) in seasons when trails are water saturated (page 41).

Strategy V. Modify Type of Use and Visitor Behavior

29. Discourage or prohibit stock (page 46).

Strategy VII. Increase the Resistance of the Resource

34. Shield the trail from impact (for example, build corduroy in boggy areas) (page 51).
35. Strengthen the trail (for example, surface the trail with gravel) (page 52).

Strategy VIII. Maintain or Rehabilitate the Resource

37. Maintain or rehabilitate the trail (for example, regularly repair water bars) (page 54).

Amount of use affects amount of trail deterioration, but is less influential than other factors. Therefore, we consider all of the tactics under strategies I (Reduce Use of the Entire Wilderness) and II (Reduce Use of Problem Areas) to be secondary tactics. They may contribute to easing problems, but they are unlikely, by themselves, to help much.

SUBPROBLEM 2—DEVELOPMENT OF UNDESIRED TRAILS

Undesired trails develop when use is not sufficiently limited to existing trails. This commonly occurs close to managed trails, in meadows, on muddy stretches, and at switchbacks. The results are multiple braided trails through meadows, wide quagmires in wet areas, and switchback shortcuts. Away from managed trails, undesired trails develop along frequently used cross-country routes and in popular destination areas. Because undesired trails are the result of too many visitors leaving the trail, such trails can be minimized either by keeping visitors on managed trails or by limiting use. Use would have to be reduced to very low levels because trails can develop with very little traffic (Weaver and Dale 1978; Cole 1987). Some of these problems are aggravated by use during seasons when impact potential is high, particularly during snowmelt in mountainous areas when soils are saturated with water. Because this problem is mostly influenced by where people walk, the primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

18. Locate trails where unwanted trails are unlikely to develop (for example, locate trails away from meadows and places likely to become muddy and build switchbacks where shortcutting is difficult) (page 35).
19. Concentrate and channel use through trail design (for example, use brush or rock to limit use to one well-defined tread) (page36).
20. Discourage or prohibit off-trail travel (for all users or just stock) (page37).

Strategy IV. Modify the Timing of Use

23. Discourage or prohibit use when soils are water saturated (page 40).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit development of new trails (for example, by prohibiting or asking users not to shortcut switchbacks or not to use trails that are just beginning to develop) (page 42).
26. Encourage certain behavior (for example, walking down the middle of the trail tread) (page 43).
27. Teach a wilderness ethic (for example, stress the importance of not creating new trails) (page 44).

Strategy VIII. Maintain or Rehabilitate the Resource

37. Close and rehabilitate undesired trails (page 54).

Amount of use affects development of unwanted trails, but is not a highly influential factor. Therefore we consider all of the tactics under strategies I (Reduce Use of the Entire Wilderness) and II (Reduce Use of Problem Areas) to be secondary tactics in most cases. There are situations, however, where problems with informal trail networks in popular destinations might be alleviated with dramatic reductions in use of these problem areas.

Campsite Deterioration

As with trail deterioration, there are problems with both the deterioration of desired campsites and the development of undesired campsites. These two subproblems are (1) excessive deterioration of individual sites and (2) the proliferation of more sites than are desired or needed. The definition of what constitutes either excessive deterioration or an excessive number of sites will depend on management objectives, the realities of area-specific use, and environmental factors.

SUBPROBLEM 1—EXCESSIVE DETERIORATION OF CAMPSITES

The primary causes of excessive deterioration of individual sites are inappropriate use, visitors spreading out on sites (enlarging campsites), and camping in fragile places. The most pronounced ongoing impact on long-established sites is site enlargement, caused by spreading out (Cole 1986). The amount of use a site receives has little effect on amount of impact, except where use levels are very low (Cole and Fichtler 1983; Marion and Merriam 1985). Erosion, for example, is unlikely to occur on a properly located site, regardless of how frequently it is used. On a poor location, however, pronounced erosion can occur even with light use. Similarly, one party of visitors can chop down more trees for firewood and tent poles and do more damage than countless parties of knowledgeable and concerned visitors. Parties that travel with stock also tend to cause more impact than backpackers (Cole 1983b). Because the most important influences on amount of deterioration are type of use, how visitors behave, and where they camp, the primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping (or only camping with stock) on certain campsites or locations (for example, places that are prone to erosion or, in lightly used areas, sites that have already been disturbed) (page 32).
17. Encourage or permit camping (or only camping with stock) only on certain campsites or locations (for example, on designated sites in popular destination areas) (page 34).
18. Locate campsites on durable sites (page 35).
19. Concentrate and channel use through site design (for example, design traffic flow on sites so that impacts do not spread) (page 36).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit particularly damaging practices and/or equipment (for example, cutting down trees or use of axes or saws) (page 42).
26. Encourage or require certain behavior, skills, and/or equipment (for example, carrying and knowing how and when to use camp stoves) (page 43).
27. Teach a wilderness ethic (for example, stress the fragility of vegetation and the need to minimize impact) (page 44).
28. Encourage or require a party size and/or stock limit (page 45).
29. Discourage or prohibit stock (page 46).
31. Discourage or prohibit overnight use (page 48).

Strategy VIII. Maintain or Rehabilitate the Resource

37. Maintain or rehabilitate campsites (page 54).

A number of secondary tactics are also available. All of the tactics under strategy I (Reduce Use of the Entire Wilderness) would tend to reduce campsite problems, but not substantially. The tactics under strategy II (Reduce Use of Problem Areas) could have more pronounced positive effects on sites in problem areas. But use reductions would have to be substantial and benefits would probably be more than offset by increased impact in areas to which use was dispersed.

The tactics under strategy II may be most useful in lightly used areas because campsite impact can be negligible if very low use levels (often no more than 1 night of use per year [Cole in press]) can be maintained. To be successful, limitations on use must be combined with tactic 16 (discouraging visitors from camping on sites with evidence of previous use), tactic 17 (encouraging visitors to camp on resistant sites), and tactics 25, 26, and 27 (teaching a wilderness ethic that will help visitors learn how to avoid damage and leave minimal evidence of their stay).

Increasing the resistance of the resource (for example, by building tent platforms or hardening sites with wood chips or gravel) could also be an effective means of avoiding excessive deterioration. Because there are other options, and extensive resource manipulation compromises wilderness goals, we consider this to be of secondary importance.

SUBPROBLEM 2—PROLIFERATION OF CAMPSITES

In most cases, the primary cause of campsite proliferation is too much use of destination areas in which use is not concentrated on a relatively small number of campsites. Usually, proliferation can be avoided simply by concentrating use. In very popular places, it may also be necessary to reduce use levels. In very lightly used places, however, proliferation can be avoided if visitors camp on sites that show no evidence of disturbance. Because the most important influence on site proliferation is where and how people camp, the primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping on previously impacted campsites (this applies to low-use areas only) and on fragile sites (this applies everywhere) (page 32).
17. Encourage or permit camping only on sites that are already well-impacted or designated (this is particularly important in high-use areas) and on resistant sites (this applies everywhere) (page 34).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit particularly damaging practices and/or equipment (for example, discourage wood fires—this is particularly important in relatively undisturbed places because fire scars tend to attract repeat use) (page 42).
26. Encourage or require low-impact behavior, skills, and/or equipment (for example, carry and use stoves—this is particularly important in relatively undisturbed places) (page 43).
27. Teach a wilderness ethic (for example, stress the need to avoid creating new campsites) (page 44).

Strategy VIII. Maintain or Rehabilitate the Resource

37. Close and rehabilitate unwanted campsites (page 54).

A number of secondary tactics are also available. All of the tactics under strategy I (Reduce Use of the Entire Wilderness) would tend to inhibit the development of unwanted campsites, but not substantially. The tactics under strategy II (Reduce Use of Problem Areas) could have more pronounced positive effects on sites in problem areas. But use reductions would have to be substantial, and benefits would probably be more than offset by increased impact in areas to which use was dispersed.

There is one exception to this generalization. The number of impacted campsites that are required to accommodate campers in popular places can be reduced if use of these places is reduced. To be successful, however, limitations on use must be combined with tactic 17 (encouraging or permitting camping only on designated or already well-impacted sites) and tactic 37 (close and rehabilitate unnecessary sites). All of the tactics under strategy II, with the exception of tactic 13 (encourage off-trail travel) could be effective in either of these situations. The consequences of increased use elsewhere must be considered.

Litter

Of all major wilderness problems, litter is potentially the simplest one to manage. The "pack-it-in, pack-it-out" policy appears to have been quite successful in reducing problems with litter; many wilderness visitors consider litter to be less abundant than it was in the past (Lucas 1985). Some of this improvement reflects the fact that wilderness rangers spend a large proportion of their time picking up litter. Clearly, visitors who leave their litter are the primary cause of litter problems. Therefore, the primary tactics are:

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit littering (and perhaps prohibit cans and bottles) (page 42).
26. Encourage or require certain behavior, skills, and/or equipment (for example, encourage visitors to pick up other visitors' litter or require litter bags) (page 43).
27. Teach a wilderness ethic (stress the importance of not littering) (page 44).

Strategy VIII. Maintain and Rehabilitate the Resource

36. Remove litter (page 52).

Strategies I and II, by reducing use where littering is a problem, would tend to reduce litter problems, but the effect would not be substantial. These tactics do not seem worth the cost—both to visitors and managers—of implementing actions.

Crowding and Visitor Conflict

Social research has demonstrated that whether visitors feel crowded or not is a function of more than how many other people they meet (Manning 1985; Stankey and Schreyer 1987). The location of the encounter makes a difference; encounters at campsites are less acceptable than those that occur while traveling, and encounters in the core of the wilderness are less acceptable than those near access points. Crowding is also affected by the type of party encountered; encounters between certain types of parties constitute visitor conflict. Encounters with large parties, parties with stock, and parties with pets are potentially more dissatisfying for some parties than encounters with parties without these characteristics. Encounters with parties that are similar to one's own party usually are most acceptable. Visitor expectations also influence the extent to which the number and type of encounters contribute to crowding (Manning 1985). Consequently, there are two relatively distinct subproblems: (1) too many encounters and (2) encounters with parties that are particularly bothersome (conflicting encounters).

SUBPROBLEM 1—TOO MANY ENCOUNTERS

The primary cause of too many encounters is simply too many people in one place at one time. This situation is influenced by the number of visitors, as well as when they visit and where they go. Consequently, the primary tactics are:

Strategy II. Reduce Use of Problem Areas

7. Inform potential visitors of the disadvantages of problem areas and/or the advantages of alternative areas (for example, inform visitors of high use levels in problem areas) (page 23).
8. Discourage use of problem areas (for example, have rangers at portals ask visitors not to visit problem areas) (page 24).
9. Limit number of users in problem areas (for example, issue a limited number of permits) (page 25).
10. Encourage or require a length-of-stay limit in problem areas (page 26).

11. Make access to problem areas more difficult and/or improve access to alternative areas (for example, build new trails into alternative areas) (page 27).
12. Eliminate facilities or attractions in problem areas and/or improve facilities or attractions in alternative areas (for example, remove shelters in problem areas) (page 28).
13. Encourage off-trail travel (page 29).
14. Establish differential skill and/or equipment requirements (more stringent requirements would be in effect in problem areas) (page 30).
15. Charge differential user fees (higher fees would be charged in problem areas) (page 31).

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping close to trails or other camps (page 32).
17. Encourage or permit camping only on dispersed campsites (page 34).
18. Locate campsites out of sight and sound of each other and trails (page 35).

Strategy IV. Modify the Timing of Use

22. Encourage use outside of peak use periods (page 39).
24. Charge fees during periods of high use (page 41).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit behavior and equipment that increase encounter frequency (for example, other parties will be less likely to notice your presence if you avoid wearing bright clothes or making lots of noise) (page 42).
26. Encourage behavior, skills, and equipment that decrease encounter frequency (for example, camp away from other parties and carry an earth-colored tent) (page 43).
27. Teach a wilderness ethic (stressing the value of minimizing contact with others) (page 44).

We consider strategy I (Reduce Use of the Entire Wilderness) to usually be a secondary strategy. Nevertheless, there are a few areas where total use should be reduced. In these places, the mere redistribution of use is insufficient and the techniques under strategy I are of primary importance. Even in such wildernesses, it would also be worthwhile to simultaneously manage internal use distribution and to modify type of use and visitor behavior to further reduce crowding and conflict.

SUBPROBLEM 2—VISITOR CONFLICT

The factors that most affect visitor conflict are the type of use and behavior of visitors encountered, where encounters occur, and visitor expectations about both the number and type of encounters. Conflicts are most severe when encounters are with dissimilar types of parties, particularly if the type of party encountered or its behavior is considered to be inappropriate. They are also severe when they occur at campsites, in more remote places, and when the encounters are unexpected. Therefore, primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit conflicting types of use (such as stock, pets, or large parties) from using certain locations (page 32).
17. Encourage or permit conflicting types of use to camp only on certain campsites or use only certain locations (page 34).
21. Segregate different types of users (page 38).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit activities that tend to cause conflict (such as playing radios or target shooting) (page 42).
27. Teach a wilderness ethic (stressing the importance of not disturbing other parties) (page 44).
28. Encourage or require a party size or stock limit (page 45).
29. Discourage or prohibit stock (page 46).
30. Discourage or prohibit pets (page 47).

Strategy VI. Modify Visitor Expectations

32. Inform visitors about appropriate wilderness uses (page 49).
33. Inform visitors about conflicting uses they may encounter (page 50).

Although visitor conflict will be reduced by tactics that reduce use of problem areas (strategy II), these are considered to be of secondary importance, in most situations, because there are more direct ways to deal with conflict. Strategy I (Reduce Use of the Entire Wilderness) is also usually a secondary strategy.

Packstock Impact

Many packstock impact problems have already been covered under trail and campsite deterioration and crowding and user conflict. The major additional type of problem is deterioration of grazing areas.

SUBPROBLEM—DETERIORATION OF GRAZING AREAS

Deterioration of grazing areas occurs mainly when grazing use is excessive or when it occurs in fragile areas or at times of the year when fragility is high. Excessive grazing can result from either too many animals or overly concentrated grazing. Because the most influential factors are amount of grazing use and where, when, and how grazing occurs, the primary tactics are:

Strategy II. Reduce Use of Problem Areas

7. Inform potential visitors of the disadvantages (such as insufficient forage) of problem areas and/or the advantages of alternative areas (page 23).
8. Discourage or prohibit stock use of problem (overgrazed) areas (page 24).
9. Limit number of stock in problem areas (for example, issue a limited number of permits) (page 25).
10. Encourage or require a length-of-stay limit for stock in problem areas (for example, limit the stay at heavily grazed meadows to 1 night) (page 26).

11. Make access (especially for stock) to problem areas more difficult and/or improve access to alternative areas (page 27).
12. Eliminate facilities or attractions in problem areas and/or improve facilities or attractions in alternative areas (for example, build hitch rails or corrals in alternative areas) (page 28).
14. Establish differential skill and/or equipment requirements (for example, require pelletized feed and use of hobbles in overgrazed areas) (page 30).
15. Charge differential user fees (for example, charge higher fees to visit heavily grazed areas) (page 31).

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping with stock in certain (overgrazed) areas (page 32).
17. Encourage or permit camping with stock in certain areas (places that are either lightly grazed or that can tolerate heavy grazing) (page 34).
18. Locate grazing facilities (such as hitch rails or corrals) on durable sites and close to areas unlikely to be overgrazed (page 35).

Strategy IV. Modify the Timing of Use

23. Discourage or prohibit stock use or grazing when areas are fragile (such as in early season or when soils are wet) (page 40).
24. Charge fees for stock when areas are fragile (page 41).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit particularly damaging grazing practices (such as picketing stock without rotating them frequently) (page 42).
26. Encourage or require behavior, skills, or equipment that minimize stock impact (such as supplemental feed and hobbling of stock) (page 43).
27. Teach a wilderness ethic (stressing the need to avoid overgrazing) (page 44).
28. Encourage or require a party size or stock limit (page 45).
29. Discourage or prohibit stock (page 46).
31. Discourage or prohibit overnight stock use (page 48).

Tactics under strategy I (Reduce Use of the Entire Wilderness), if applied to stock, would tend to reduce this problem, but these usually are of only secondary importance.

Human Waste

Human waste becomes a problem only where use is relatively high. Elsewhere, decomposition usually eliminates wastes before they become a problem. As use grows, it becomes increasingly important for users to dispose of waste properly (Temple and others 1982). Where heavy use is highly concentrated, the only means of avoiding problems is to provide regularly maintained toilet facilities or to reduce amount of use. Therefore, primary tactics are:

Strategy II. Reduce Use of Problem Areas
(These tactics should only be necessary in very heavily used places.)

7. Inform potential visitors of the disadvantages (such as overcrowding) of problem areas and/or the advantages of alternative areas (page 23).
8. Discourage use of problem areas (page 24).
9. Limit number of visitors in problem areas (issue a limited number of permits) (page 25).
10. Encourage or require a length-of-stay limit in problem areas (page 26).
11. Make access to problem areas more difficult and/or improve access to alternative areas (for example, close roads that lead to trailheads that provide access to problem areas) (page 27).
12. Eliminate facilities or attractions in problem areas and/or improve facilities or attractions in alternative areas (for example, remove shelters but leave toilets in problem areas) (page 28).
13. Encourage off-trail travel (page 29).
14. Establish differential skill and/or equipment requirements (for example, require certification of knowledge of minimum impact techniques to visit problem areas) (page 30).
15. Charge differential user fees (for example, charge higher fees to visit problem areas) (page 31).

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping where waste disposal is a problem (page 32).
17. Encourage or permit camping only where toilets are provided (in heavily used areas) (page 34).
18. Locate campsites where waste disposal will not be a problem (for example, where soil is deep) (page 35).
19. Concentrate human waste by providing toilets (page 36).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit improper waste disposal (such as disposal on the surface) (page 42).
26. Encourage or require certain behavior, skills, and/or equipment (for example, a trowel for shallow individual burial of waste) (page 43).
27. Teach a wilderness ethic (stress the need for proper waste disposal) (page 44).

Strategy VII. Increase the Resistance of the Resource
(This tactic should only be necessary in very heavily used places.)

34. Shield the site from impact by providing toilets (page 51).

Strategy VIII. Maintain or Rehabilitate the Resource

36. Remove waste from certain types of toilets (this tactic should only be necessary in very heavily used places) (page 53).

Reducing use of the entire wilderness (strategy I) will tend to reduce problems. Again we feel that these tactics are of only secondary importance, as there are more direct and effective means of dealing with waste problems.

Wildlife and Fishery Impacts

Less is known about the severity and causes of wildlife and fishery impacts than some of the preceding problems (Starkey and Larson 1987). Destruction of habitats, caused by human impact on vegetation and soil, can have an adverse effect, particularly on smaller animals (Ream 1980). Because this occurs primarily at campsites and along trails, mitigation strategies are similar. Probably the most important unique subproblems caused by recreational use are (1) unintentional disturbance (harassment) of large mammals and birds; (2) competition between recreational stock, domestic livestock, and wild animals; and (3) attraction of animals, such as bears, rodents, and jays, through feeding or improper food storage. Hunting, fishing, and the planting of fish are separate issues that we consider beyond the scope of the management techniques we are discussing here.

SUBPROBLEM 1—HARASSMENT

Disturbance of wildlife is most strongly related to user behavior and where and when use occurs (Ream 1979). Disturbance is most serious when it occurs in critical breeding, feeding, or watering areas or at times of the year when animals are weak or engaged in reproduction. Because many animals will not be disturbed substantially by occasional contact with humans, reducing use in problem areas can also be a useful strategy, but only if use can be kept at very low levels. Primary strategies and techniques are:

Strategy II. Reduce Use of Problem Areas
(Here problem areas are critical wildlife areas.)

7. Inform potential visitors of the disadvantages of critical areas and/or the advantages of alternative areas (for example, advertise the attractiveness of other areas) (page 23).
8. Discourage or prohibit use of critical areas (such as areas around desert water holes) (page 24).
9. Limit number of users in critical areas (issue a limited number of permits) (page 25).
10. Encourage or require a length-of-stay limit in critical areas (page 26).
11. Make access to critical areas more difficult and/or improve access to alternative areas (page 27).
12. Eliminate facilities or attractions in critical areas and/or improve facilities or attractions in alternative areas (page 28).
14. Establish differential skill and/or equipment requirements (for example, require a special certification to visit critical areas) (page 30).
15. Charge differential user fees (higher fees to visit critical places) (page 31).

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping in critical locations (page 32).
17. Encourage or permit camping only on certain campsites and/or locations (away from critical areas) (page 34).
18. Locate facilities (such as trails and campsites) away from critical areas (page 35).
20. Discourage or prohibit off-trail travel (page 37).

Strategy IV. Modify the Timing of Use

23. Discourage or prohibit use when disturbance potential is high (page 40).
24. Charge fees when disturbance potential is high (to reduce use) (page 41).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit disturbing behavior (such as approaching animals) (page 42).
26. Encourage behavior that minimizes wildlife disturbance (page 43).
27. Teach a wilderness ethic (stressing how easily wildlife is disturbed) (page 44).
30. Discourage or prohibit pets, particularly those running loose (page 47).
31. Discourage or prohibit overnight use in critical areas (page 48).

Tactics under strategy I (Reduce Use of the Entire Wilderness) are of secondary importance.

SUBPROBLEM 2—COMPETITION

Competition becomes a problem when excessive grazing occurs in areas where wildlife feed. Because the factors that affect problem severity are amount of grazing, grazing behavior, and where and when grazing occurs, the primary tactics are:

Strategy II. Reduce Use of Problem Areas
(Here problem areas are areas where competition occurs.)

7. Inform potential visitors with stock of the disadvantages of problem areas and/or the advantages of alternative areas (page 23).
8. Discourage or prohibit stock use of problem areas (page 24).
9. Limit number of stock users in problem areas (page 25).
10. Encourage or require a length-of-stay limit for parties with stock in problem areas (page 26).
11. Make access to problem areas more difficult for stock users and/or improve access to alternative areas (page 27).
12. Eliminate stock facilities or attractions in problem areas and/or improve facilities or attractions in alternative areas (page 28).
14. Establish differential skill and/or equipment requirements (such as requiring the use of supplemental horse feed in problem areas) (page 30).
15. Charge differential user fees (for example, higher fees to visit places where competition is likely) (page 31).

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping and/or stock use in certain locations (where competition is likely) (page 32).
17. Encourage or permit camping and/or stock use only on certain campsites and/or locations (designate sites away from places where competition is likely) (page 34).
18. Locate facilities (such as corrals and campsites) away from problem areas (page 35).
20. Discourage or prohibit off-trail stock travel (page 37).

Strategy IV. Modify the Timing of Use

23. Discourage or prohibit stock use when competition with wildlife is likely (page 40).
24. Charge fees for stock use when competition with wildlife is likely (to reduce use) (page 41).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit grazing in problem areas (page 42).
26. Encourage behavior, skills, and use of equipment that minimize competition (such as use of pelletized feed) (page 43).
27. Teach a wilderness ethic (stressing problems of competition between stock and wildlife for food) (page 44).
28. Encourage or require a party size and stock limit (page 45).
29. Discourage or prohibit stock (page 46).
31. Discourage or prohibit overnight use with stock (page 48).

Tactics under strategy I (Reduce Use of the Entire Wilderness) are of secondary importance.

SUBPROBLEM 3—ATTRACTION AND FEEDING OF ANIMALS

This problem can be serious, especially in bear country. Although attraction of smaller animals is less serious to humans, it can have a profound impact on those animals affected. The primary cause of problems is improper behavior—either feeding animals or storing foods inadequately. Because bear problems can be particularly pronounced in some locations, where people camp can also be an influential factor. Therefore, the primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping where bear encounters are likely (page 32).
17. Encourage or require camping only on designated sites or in places away from bear concentrations (page 34).
18. Locate campsites in places where bear encounters are unlikely (page 35).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit feeding animals or camping practices that will attract animals (page 42).
26. Encourage or require camping behaviors that will not attract animals (page 43).
27. Teach a wilderness ethic (stress the need to not disrupt animals through feeding or improper food storage) (page 44).

Strategy VII. Increase the Resistance of the Resource

34. Provide high cross-bars for hanging food in camp (page 51).

All of the techniques under strategies I (Reduce Use of the Entire Wilderness) and II (Reduce Use of Problem Areas) are secondary techniques.

Water Pollution

The severity and causes of recreation-related water pollution problems are even less well understood (Hermann and Williams 1987). Health hazards due to fecal contamination of water have been dealt with under human waste problems. The few attempts to evaluate the extent of fecal contamination in wilderness have found little evidence of problems, even in quite heavily used areas (see, for example, Silverman and Erman 1979). More insidious, and even harder to document, is the subtle deterioration that results from pollution of water bodies. In the same lakes where fecal contamination was generally absent, Taylor and Erman (1979) found changes in ion concentrations and aquatic flora and fauna. Such changes represent profound changes in the composition and function of natural water bodies.

SUBPROBLEM—CONTAMINATION OF WATER BODIES (FROM POLLUTANTS OTHER THAN FECES)

The primary factors that affect the severity of water pollution probably are where and how visitors camp. Therefore, primary tactics are:

Strategy III. Modify the Location of Use Within Problem Areas

16. Discourage or prohibit camping and/or stock use close to water (page 32).
17. Encourage or permit camping and/or stock use only on certain campsites and/or locations (away from water) (page 34).
18. Locate facilities (such as trails and campsites) away from water (page 35).

Strategy V. Modify Type of Use and Visitor Behavior

25. Discourage or prohibit visitor behavior that causes pollution (for example, using soap in water bodies) (page 42).
26. Encourage behavior, skills, and use of equipment that minimize pollution (for example, how to bathe without polluting waters) (page 43).
27. Teach a wilderness ethic (stress the need to avoid pollution of water bodies) (page 44).

Reductions in use will tend to decrease the potential for water pollution problems, but amount of use is a less influential factor than location of use and visitor behavior. Consequently, all techniques under strategies I and II are of secondary importance.

MANAGEMENT TACTICS

In the remainder of this report we describe each management tactic. Here, we have tried to offer information that will enable the manager to decide about which tactics to select. Under each tactic, we provide the following information:

Purpose—What the tactic is meant to accomplish.

Description—An expanded description of the tactic, how it works, and examples of how it might be implemented.

Current Usage—The extent of current usage, based on the Washburne and Cole (1983) survey of wilderness managers taken in 1980. Usage was classified as "common" if practiced by more than 20 percent of area managers. (Very few techniques were practiced by much more than 20 percent of managers.) Other classifications were "infrequent" (practiced in 5 to 20 percent of areas), "rare" (practiced in less than 5 percent of areas), and "none" (no areas use the technique). Data on usage are also available in Bury and Fish (1980) and Fish and Bury (1981). For tactics not covered in the survey, usage is unknown, although we describe the probable extent of usage, based on personal observation and discussions with managers.

Costs to Visitors—We consider opportunities for "primitive and unconfined recreation" to be one of the most important values of wilderness. Anything that diminishes such opportunity is a cost to visitors. When evaluating visitor costs, the following factors must be considered: effect on freedom of choice, obtrusiveness of the technique, when and where the visitor is affected, the number of visitors affected, the importance visitors attach to affected activities, and effects on the ability of visitors to engage in wilderness-dependent activities and obtain wilderness-specific values.

Although we have little substantiating data, we believe that costs to visitors are highest when freedom of choice is eliminated by regulations. Information, education, and persuasion are less costly than rules because visitors retain freedom of choice. The important and common exception occurs where regulation is required to ensure the effectiveness of a program. In such cases regulation promotes the interests of conscientious users (Dustin and McAvoy 1984). Costs are also higher when visitors are aware that they are being managed, in contrast to subtle techniques that leave visitors unaware of being managed. In this regard, persuasive techniques (in which managers ask visitors to do or not do certain things) are no more subtle than regulations, although they do preserve freedom of choice. The least costly techniques are offsite education, information, and site manipulation.

Costs to visitors are high when their activities are controlled onsite, as opposed to techniques that do not constrain visitor choices once they enter the wilderness. Costs are also high when visitors are not aware of management programs until after arriving at the area. For example, costs are high for visitors who are required to stick to a fixed itinerary of assigned campsites every night, particularly if they are not aware of the requirement until reaching the wilderness. A less costly means of rationing and controlling use distribution is to establish a quota for trailheads (but allow free movement within the wilderness). Costs would be particularly low if visitors were made aware of trailhead quotas during the planning stages of their trip because they could alter their plans if this constraint was unacceptable.

Total visitor costs also increase as more visitors are affected by an action. For example, in most wildernesses, prohibiting campfires is much more costly than prohibiting stock because many more people are affected. But this rule (that cost increases as the number of affected users increases) must be tempered by a consideration of the importance visitors attach to the activities they are being asked to forgo. For example, requiring visitors to pack out their litter may be less costly than prohibiting stock—even though more people are affected—because packing out litter is less of a burden than not being allowed to use stock.

Tactics that reduce opportunities for wilderness-dependent activities are particularly costly to visitors. For example, prohibiting all overnight use and allowing only day use can reduce certain problems, but this tactic would seriously limit opportunities to enjoy unique wilderness values such as isolation, challenge, and contemplation.

No type of action can minimize all of these costs. Instead, it will be necessary to balance all of these considerations and try to minimize the aggregate costs of an action. Thus, a regulatory action that affects few visitors offsite may be less costly than a nonregulatory action that affects many visitors onsite.

Costs to Management—It is also important to consider the cost to management of implementing an action. In some cases it can be counterproductive to undertake a program that cannot be effectively implemented due to insufficient funds. For example, it is common for regulations to be established that cannot be adequately enforced. Relocating access points and trails could be very effective in managing certain problems, but current budgets are probably inadequate for many substantial projects. Both short-term and long-term costs need to be considered. Although it is difficult to define costs, particularly in dollar terms, we do attempt some general estimates.

Effectiveness—In this section, we discuss how effective the tactic is likely to be, as well as means of increasing effectiveness. We note situations (such as high- or low-use areas) in which the tactic is likely to be more or less effective than elsewhere. We also mention other tactics that, when used to complement the one being described, increase effectiveness.

Comments—A variety of issues are discussed in this section. A particularly common item of discussion is any likely side effect that should be considered before implementing an action. Most actions taken to mitigate a certain problem, in a specific place, will affect other problems and places. These likely consequences should be understood and planned for. We also mention the acceptability of the technique to users where this is known or can be estimated.

Sources—Finally, we list published sources of information that are relevant to the tactic. These often provide either further discussion of the technique or data useful in evaluating effectiveness, appropriateness, or visitor reaction to the technique. Brief annotations on each source are included in the references section.

Strategy I. Reduce Use of the Entire Wilderness

TACTIC 1: LIMIT NUMBER OF VISITORS IN THE ENTIRE WILDERNESS

PURPOSE

To limit total use directly so that the social and/or ecological impacts of use are reduced.

DESCRIPTION

Require a permit to visit the wilderness and limit the number of permits. Permits are usually issued for groups rather than individuals, and quotas are usually set to limit the number of entrants per day. A more complicated system seeks to prevent the number of visitor groups from exceeding an established number at any time. To do this, with the variation in lengths of stay that always exist, requires a system for calculating numbers of visitors present per day. In effect, the number of expected departures on any day determines how many visitors can enter that day. Various options for allocating and issuing a limited number of permits, such as advanced reservations, first-come, first-served, lotteries, etc., exist (Stankey and Baden 1977).

CURRENT USAGE

Rare. Most areas that limit number of visitors also control internal use distribution (tactic 9).

COSTS TO VISITORS

Low to high. Costs depend on the proportion of visitors who cannot obtain permits and the difficulties associated with applying for a permit. Costs are high for visitors who are denied access to the wilderness on the desired date, especially repeatedly, but low for some visitors with flexible schedules. Visitors tend to support actions limiting use where necessary (Fazio and Gilbert 1974; Stankey 1979). Moreover, if advance reservations can be made, costs are incurred offsite and can be limited to the planning stages of trips. Thus, areawide use limitation does not restrict visitor freedom and spontaneity as much as use limitation techniques that control internal use distribution. Costs can also be high, however, for visitors with unpredictable leisure schedules if the application process demands advance planning. If use is reduced substantially, visitors who obtain permits may find conditions more enjoyable.

COSTS TO MANAGEMENT

Moderate to high. Costs are associated with development, maintenance, and enforcement of the permit system. Extended office hours and special locations for issuing permits are often necessary to minimize costs to visitors.

EFFECTIVENESS

This is likely to be an effective means of maintaining the status quo. But current problem areas are unlikely to improve substantially because internal use distributions are unaffected. Some redistribution from peak times to times of lower use is likely. This technique is most useful in small areas where use must be limited, but where the existing distribution of use and impact is acceptable. Tactic 9 (limit number of visitors in problem areas) is more generally useful.

COMMENTS

Visitor dissatisfaction can be minimized by clearly communicating the need for use limits. Varying needs of visitors are served best by issuing permits such that (1) access can be obtained during the planning stages of trips (by allowing for advance reservations or a lottery) and, also, (2) allowing some opportunities for spontaneous trips (by leaving some permits available first-come, first-served on or immediately preceding the start of the trip). Usually a specified percentage of permits is available for advance reservations and the remainder for drop-ins. Visitors generally find lotteries less acceptable than other rationing techniques, unless they have had experience with lotteries (as on some whitewater rivers). All tactics involving permits or fees have the side benefit of causing direct contact between managers and visitors, which provides a communication opportunity.

SOURCES

Hendee and Lucas (1973, 1974), Behan (1974), Fazio and Gilbert (1974), Stankey and Baden (1977), Stankey (1979), Bultena and others (1981a), McCool and Utter (1981), Roggenbuck and others (1982), Shelby and others (1982), Stankey and Schreyer (1987).

Strategy I. Reduce Use of the Entire Wilderness

TACTIC 2: LIMIT LENGTH OF STAY IN THE ENTIRE WILDERNESS

PURPOSE

Provided that this technique does not result in more frequent visits, total use (visitor-days, for example) will be reduced as length of stay is reduced.

DESCRIPTION

Such a limit could be a regulation with a specific time limit or, through information, visitors could be asked to keep lengths of stay short. A permit system would be necessary to provide a record of entry date and a means for enforcing a regulation limiting length of stay.

CURRENT USAGE

Common. For example, Glacier National Park limits stays to 6 nights. Usually limits are not intended to reduce use, however. They are most common where demand greatly exceeds established use limits (such as on whitewater rivers). In such places length-of-stay limits augment a direct limit on numbers of users (tactic 1), allowing more visitors access to a limited number of permits.

COSTS TO VISITORS

Low to moderate. Costliness depends on allowed length of stay. Costs are low under the most common current limit of 14 days. Shorter limits would be more costly. Costs are high for visitors who desire the experience of an extended wilderness trip but cannot take a long trip. Costs are incurred onsite, affecting the trip itself, although negative effects can be reduced by making visitors aware of regulations during the planning stages of their trip.

COSTS TO MANAGEMENT

Low to high. Costs will be high unless a permit system is already in effect; if so, additional costs will be low. If limits are regulated, costs are incurred due to the need to develop and maintain a mandatory permit system and to enforce limits. Otherwise the primary cost is information dispersal.

EFFECTIVENESS

Unlikely to reduce total use appreciably. Most wilderness visits are short. Almost half of visits are for less than a day, and the average stay for overnight users is only 3 days (Washburne and Cole 1983). Therefore, length-of-stay limits usually would reduce use very little. Limits would generally have to be a week or less, completely precluding even moderate length trips, before a length-of-stay limit would reduce total use substantially. Stay limits would tend to shift use distribution toward the periphery of areas, with resulting shifts in impacts.

COMMENTS

In our opinion, such limits are justified only where demand greatly exceeds use limits, total use is directly limited by permit, and a substantial proportion of parties desire a trip that exceeds proposed stay limits. Under these circumstances, limits would allow access to more visitors, although changing the type of experience for those who wanted to stay longer. Length-of-stay limits in selected popular parts of the wilderness—without limits elsewhere—would usually be equally effective **and** still provide opportunities for extended wilderness trips. Even though few visitors take trips with very long stays, such trips seem important in relation to wilderness values. Eliminating the chance for long trips seems unfortunate. Encouraging day-use in place of camping seems inconsistent with wilderness goals.

SOURCES

None

Strategy I. Reduce Use of the Entire Wilderness

TACTIC 3: ENCOURAGE USE OF OTHER AREAS

PURPOSE	To reduce total use of the wilderness, particularly by people who place lower values on the area's wilderness characteristics, to reduce social and ecological impacts.
DESCRIPTION	Tell prospective visitors about alternative places, particularly nonwilderness areas, and encourage them to go there. This could involve maps, brochures, answers to inquiries, and personal suggestions.
CURRENT USAGE	Infrequent. Programs to disperse use within the wilderness are more common.
COSTS TO VISITORS	Low. If information is presented accurately and without pressure, there should be almost no cost to visitors, and at least some visitors could find areas that better match their preferences. There could be costs to the current visitors to the other areas, however, if they have to contend with more visitors and their impact.
COSTS TO MANAGEMENT	Low. Might include costs for a brochure or map, but most information would be included in normal contacts with visitors. Training and preparation of background information materials would entail some costs.
EFFECTIVENESS	Unknown. Tests of use redistribution efforts have all been concerned with redistribution within a wilderness—not to other areas. Those studies have shown mixed results, but adequate information, well presented and in a timely way, has resulted in substantial shifts in use. We would expect moderate effectiveness of programs to shift some use to other areas.
COMMENTS	This technique deserves more use. It is nonauthoritarian and potentially helpful to visitors. Diverting some people less dependent on wilderness conditions to nonwilderness areas seems very desirable. Caution is needed to avoid arm-twisting. Information must be presented with ethical sensitivity; it must be truthful (don't say there is good fishing if fishing is actually poor). It is even more difficult to decide whether to omit information about attractions or problems. Too much information might reduce visitors' sense of discovery.
SOURCES	Lime and Lucas (1977), Roggenbuck and Berrier (1981), Krumpe and Brown (1982).

Strategy I. Reduce Use of the Entire Wilderness

TACTIC 4: REQUIRE CERTAIN SKILLS AND/OR EQUIPMENT

PURPOSE	By requiring certain skills or equipment, some potential visitors not possessing these skills or equipment will not be able to enter the area. This will reduce use.
DESCRIPTION	Require evidence of skill, usually in minimum-impact use, either through completion of an acceptable course or passing a test, and/or require possession and use of equipment that reduces social and ecological impacts, such as tents with their own poles; gas camp stoves; tents of subdued, natural colors; high-line hitching ropes for tying horses; etc.
CURRENT USAGE	None. Untried for purposes of reducing use. It has been used to modify type of use (tactic 26), particularly on whitewater rivers and for mountain climbers, for safety and low-impact reasons.
COSTS TO VISITORS	Low to moderate. Poses high costs for those visitors unable or unwilling to meet test or equipment requirements, or who feel the test is unfair. For others, costs are the time, effort, and money required to qualify. These costs need not be high relative to those associated with the trip itself. Costs are incurred offsite and during the planning stages of trips. Some required skill or equipment may contribute to more enjoyable trips for visitors.
COSTS TO MANAGEMENT	Moderate to high. Test development and administration, enforcement, and employee training will all add to costs. Testing skills would usually cost more than checking equipment. If other organizations, schools, and so on, did much of the skill testing, costs would be lower. Costs will be ongoing. Such requirements would be difficult to enforce without a permit system, with its associated costs.
EFFECTIVENESS	This technique will be effective only if skill and equipment requirements are so stringent that many potential visitors are eliminated. Moreover, the strategy of reducing total use is seldom of more than secondary importance for solving problems.
COMMENTS	This technique is likely to be much more useful as part of a program to modify character of use and reduce per capita impacts than to reduce total use. Acceptability to visitors varies from low to moderate.
SOURCES	Hardin (1969), Stankey and Baden (1977), Bultena and others (1981a), McCool and Utter (1981), Shelby and others (1982), Stankey and Schreyer (1987).

Strategy I. Reduce Use of the Entire Wilderness

TACTIC 5: CHARGE A FLAT VISITOR FEE

PURPOSE

By charging a fee, potential visitors who are unable or unwilling to pay the fee will not be able to enter the area. This will reduce use.

DESCRIPTION

Charge all visitors the same fee at all times. The fee could be per person or per group, and could be an entry fee, regardless of trip length, a daily fee, or even an annual fee.

CURRENT USAGE

Apparently untried for purposes of reducing use. Fees are charged on a few whitewater rivers, primarily to offset the costs of administering a permit and reservation system. Many National Parks charge an entrance fee, but this only indirectly affects use of wilderness/backcountry.

COSTS TO VISITORS

Low to moderate. Costliness would depend on the amount of the assessed fee. This technique could be costly to visitors who cannot afford the fee. Generally, however, fees would be low compared to other costs associated with the trip itself. Costs are incurred offsite. Negative effects can be reduced by making visitors aware of costs during the planning stages of their trip.

COSTS TO MANAGEMENT

Moderate to high. Costs are associated with administration of the permit system, fee collection, enforcement, and management of funds. The cost/benefit ratio for this technique would depend on the extent to which the programs of managing agencies would benefit from revenues generated. Fees usually would require a permit system, with its usual costs, to be enforceable. Annual fees—in effect a license—could operate without a permit system.

EFFECTIVENESS

To be effective, fees must be high enough to reduce use significantly. To be equitable, however, fees should not be so high that highly motivated but poor visitors could not afford to visit. Different types of fees would have different effects. A daily fee would tend to shorten visits; a per-trip fee would reduce numbers of visitors but not lengths of stay. An annual fee would probably reduce numbers of visitors but might result in more trips or longer trips as people try to "get their money's worth."

COMMENTS

A fee may be more useful as a source of revenue and a means of supporting management costs than as a management tool. As a management tool, differential user fees (tactics 15 and 24) are likely to be more efficient in dealing with specific problems than flat fees. Acceptability to visitors varies from low to high. Many visitors object to the principle of a use fee in wilderness; for others, acceptability depends on pricing. Visitors usually accept fees better if they know most funds will be used to manage and protect the area they are visiting. Authority to charge entrance fees to wilderness is not now available, although some places charge a fee for processing reservations.

SOURCES

Echelberger and Moeller (1977), Stankey and Baden (1977), Bultena and others (1981a), Roggenbuck and others (1982), Stankey and Schreyer (1987).

Strategy I. Reduce Use of the Entire Wilderness

TACTIC 6: MAKE ACCESS MORE DIFFICULT THROUGHOUT THE ENTIRE WILDERNESS

PURPOSE

Use levels throughout the wilderness could be reduced if it was more difficult to either reach the wilderness or move about within the wilderness.

DESCRIPTION

Access could be made more difficult by closing some of the access roads and trails, by maintaining them to a lower standard, or by removing bridges. Selective changes in the difficulty of access will also alter internal use distributions (tactic 11).

CURRENT USAGE

Unknown. It is doubtful that access is being made more difficult for this purpose in many areas. Usually access becomes more difficult either because there are insufficient funds to maintain road or trail systems or because access to selected places, rather than to the entire wilderness, is made more difficult.

COSTS TO VISITORS

Low to high. Visitors retain freedom of choice about where they can go, and management presence is subtle. Visitors who are not informed of difficult access may be exposed to undesirable hazards, however. Costs can be high for those visitors who cannot reach the area or desired destinations within the area. Visitors who have been to the area before may be bothered by the changes they encounter.

COSTS TO MANAGEMENT

Low to moderate. The major costs would be information dissemination and, in some cases, road closure, trail reconstruction, etc. In the long run, reduced maintenance could create problems that would be costly to correct.

EFFECTIVENESS

This technique could be effective in reducing use and, therefore, reducing problems, particularly with crowding, human waste, and wildlife disturbance.

COMMENTS

Visitor dissatisfaction should not be severe if there are other areas in the vicinity in which access is easier. Visitor acceptance of this technique is divided.

SOURCES

Stankey (1973, 1980).

Strategy II. Reduce Use of Problem Areas

TACTIC 7: INFORM POTENTIAL VISITORS OF THE DISADVANTAGES OF PROBLEM AREAS AND/OR ADVANTAGES OF ALTERNATIVE AREAS

PURPOSE	By convincing visitors that they will have "better" experiences outside of problem areas, it should be possible to reduce use of problem areas. Problem areas can be lake basins, drainages, or other large destination areas.
DESCRIPTION	A wide variety of information could be provided to potential visitors (such as use densities, availability of campsites and horse forage, fishing opportunities, difficulty of travel, bear problems, and scenic attractions). Information can be provided in various formats, from written materials to personal contact. Information provided in guidebooks can be screened, and additions or deletions can be suggested to guidebook authors.
CURRENT USAGE	Common. This is one of the more popular techniques in current use.
COSTS TO VISITORS	Low. As long as the information is accurate and managers do not attempt to pressure visitors to visit or avoid certain areas, there are few costs to visitors. There could be costs to the current visitors of alternative areas if they have to contend with many new visitors and their impacts.
COSTS TO MANAGEMENT	Low to moderate. Some costs are incurred in the preparation and dispersal of information. Such information may require frequent updating.
EFFECTIVENESS	Lucas (1981) discusses means of increasing the effectiveness of use dispersal through information programs. It is particularly important to provide enough information so that visitors can choose settings that match their desires (use density information is not sufficient). It is also important to get information to visitors during the planning stage of their trips.
COMMENTS	Provision of information can have the added benefit of increasing visitor satisfaction by better matching the desires of visitors with their subsequent experiences. It is important to consider the ethics of providing selective information intended to influence visitors' choices. Information on fishing or hunting opportunities should be phrased so as not to focus excessive pressure on certain areas. Moreover, it is important to plan for increased use of alternative areas, particularly if specific areas are being advertised. Where specific areas are being advertised it is probably easier to manage the effects of altered use distributions because it will be easier to predict where increased use will occur. Visitor support for this technique is high.
SOURCES	Lime and Lucas (1977), Lucas (1981), Martin and Taylor (1981), Roggenbuck and Berrier (1981), Krumpe and Brown (1982), Roggenbuck and others (1982).

Strategy II. Reduce Use of Problem Areas

TACTIC 8: DISCOURAGE OR PROHIBIT USE OF PROBLEM AREAS

PURPOSE

To reduce or eliminate visitor use of problem areas. Prohibiting use should cause a more dramatic reduction in amount of use than discouraging use.

DESCRIPTION

Visitors can be asked not to visit problem areas or visiting problem areas can be made illegal. Closures can apply to specific trails, destination areas, or larger areas within the wilderness, and can be temporary or long term.

CURRENT USAGE

Infrequent. The most common reason for closure of entire areas is to avoid wildlife disturbance or conflict. Some of these closures apply only in certain seasons (tactic 23). A few areas have also closed specific trails. Both Glacier and Yellowstone National Parks, for example, close areas where grizzly bear encounters are likely. The number of areas that discourage but do not prohibit use of certain areas is unknown, but this action is probably common. Closure of specific campsites or of campsites in certain environments—such as meadows—is most common; this is tactic 16.

COSTS TO VISITORS

Low to moderate. Costs depend on the number and desirability of closed places, as well as the availability of desirable alternatives. Costs are high for those visitors who want to visit closed areas. Discouraging use is less costly than prohibiting use because visitors retain freedom of choice; however, this shifts the burden of cost to those conscientious visitors who voluntarily choose to go elsewhere. Costs can be minimized by making visitors aware of closures during the planning stage of their trip, making certain that attractive alternative locations exist, and seeing that visitors are made aware of these alternatives. It is also desirable to provide a good rationale for closures to visitors.

COSTS TO MANAGEMENT

Moderate to high. Costs depend on the number of closures and whether closures are required or encouraged. Costs are higher for prohibiting use than discouraging it. Costs include signing, other types of information dissemination, and enforcement of prohibitions.

EFFECTIVENESS

Area closures can be an effective way to deal with wildlife disturbance problems, or reducing the risks of human-grizzly bear encounters. They may also be an effective solution to documented water pollution problems. Any advantages in reduced crowding or visitor conflict are probably offset by the costs to visitors of access denial. Compliance with closures can be increased by explaining reasons for closures, providing visitors with information prior to entry, providing reasonable alternative use locations, and enforcing closures.

COMMENTS

Problems resulting from increased use of other trails or areas must be considered.

SOURCES

Parsons (1979).

Strategy II. Reduce Use of Problem Areas

TACTIC 9: LIMIT NUMBER OF VISITORS IN PROBLEM AREAS

PURPOSE

Reduce the number of visitors to problem areas directly through a permit system.

DESCRIPTION

A limited number of permits are issued for problem areas. Permits can be issued for specific trailheads, travel zones, individual campsites, or campgrounds.

CURRENT USAGE

Infrequent, but implementation of rationing systems that control internal use distribution is becoming increasingly common. It is currently much more common in the National Park Service than elsewhere. But managers of most wildernesses perceive a need for rationing in the future. Rationing by trailhead, travel zone, or camping area is about equally common at present.

COSTS TO VISITORS

Low to high. Costs depend on how much demand exceeds the supply of permits (this affects the probabilities of visitors being denied access), how visitors obtain permits, and whether permits are issued for trailheads, travel zones, or campsites. Clearly, costs increase as the likelihood of obtaining a permit decreases. Except for a few places during peak use periods, permits are now difficult to obtain only on a handful of wilderness whitewater rivers. Costs to visitors in reduced freedom and spontaneity increase from systems where permits are issued for trailheads to those where permits are issued for travel zones to those where permits are issued for specific campsites. Limiting use by travel zones or campsites restricts visitors' freedom of movement within the area. Trailhead quotas do not limit movement within the area, although some visitors may not be able to enter at their first-choice location. Permits can be made available first-come, first-served, by reservation, or through a lottery. Each favors a select clientele. Local visitors are favored by the first-come, first-served approach; visitors who are able to plan far ahead are favored by the reservation and lottery approaches. Most areas use a combination of approaches to minimize costs for individual clienteles. Lotteries are currently confined to whitewater rivers where demand greatly exceeds the supply of permits.

COSTS TO MANAGEMENT

High. Costs are incurred in developing and maintaining a system for allocating and distributing permits and enforcing permit compliance. Lotteries and reservations are more costly than a first-come, first-served system. Managerial costs also decrease as the level of control of internal use distribution decreases, because compliance problems are reduced. Thus, trailhead quota systems are less costly than systems based on travel zones or campsites.

EFFECTIVENESS

This technique is an effective means of reducing use in problem areas. It can be useful in dealing with crowding problems. When combined with techniques that influence the location of use (strategy III) and visitor behavior (strategy V), it can also help mitigate campsite deterioration, wildlife disturbance, and packstock impact problems.

COMMENTS

As before, the consequences of increased use and impact elsewhere must be considered. It is usually undesirable to spread use uniformly, as this does not provide diversity of conditions and experiences. Trailhead quotas generally provide the optimum balance between effective control of internal use distribution and allowing visitors free and spontaneous movement. Several simulation models exist that can help match trailhead quotas to desired use (Peterson 1977) and encounter levels (Shechter and Lucas 1978; Potter and Manning 1984; Rowell 1986). Providing opportunities for both advanced planning and last-minute trips, by issuing some permits by reservation and others first-come, first-served, also seems desirable. Visitors tend to support use limitations where they are perceived as necessary to prevent overuse. But visitors who are not familiar with lotteries tend to dislike them. Most visitors strongly dislike being required to stick to a fixed itinerary—a common requisite when permits are issued for travel zones and particularly for specific camping areas.

SOURCES

Hendee and Lucas (1973, 1974), Behan (1974), Fazio and Gilbert (1974), Greist (1975), Echelberger and Moeller (1977), Peterson (1977), Stankey and Baden (1977), Shechter and Lucas (1978), Stankey (1979), Lucas (1980), Bultena and others (1981a, 1981b), McCool and Utter (1981), Parsons and others (1981), Plager and Womble (1981), van Wagtendonk (1981), Roggenbuck and others (1982), Potter and Manning (1984), Parsons (1986), Rowell (1986), Stankey and Schreyer (1987).

Strategy II. Reduce Use of Problem Areas

TACTIC 10: ENCOURAGE OR REQUIRE A LENGTH-OF-STAY LIMIT IN PROBLEM AREAS

PURPOSE

By reducing the amount of time that visitors spend in problem areas, total use of these areas is reduced.

DESCRIPTION

Either enforce regulations with a specific time limit or, through provision of information, visitors can be asked to stay only a short time in specific areas. Limits could apply to specific destination areas or larger management units.

CURRENT USAGE

Unknown, but probably rare for purposes of reducing use in problem areas. Regulations on stay seem much more common than encouraging shorter stays. We are aware of some areas with regulated limits in some places. Usually these augment direct limits on numbers of visitors, allowing more visitors access to a limited number of permits. They are most common in wildernesses where limits apply only to use of whitewater rivers. Length-of-stay limits at individual campsites are common; limits are usually 14 days. This action is generally taken to avoid "homesteading," the situation where one party takes over a site for an extended period. It is really a prohibition on a particularly damaging practice—see tactic 25—and it has essentially no effect on amount of use.

COSTS TO VISITORS

Low. Visitors have the option of visiting areas where limits are not imposed. But visitors who choose to visit problem areas anyway will experience some loss of freedom with its associated costs. Negative consequences can be minimized by getting information about area-specific limits to users during the planning stage of their trip.

COSTS TO MANAGEMENT

Low to moderate. Where limits are encouraged rather than required, information dispersal will be the primary cost. Where limits are required, the need for a permit system and enforcement will increase costs substantially.

EFFECTIVENESS

Parsons (1983) describes how a 1-night use limit in a popular part of Kings Canyon National Park reduced visitor nights by a factor of two, despite a 35 percent increase in the number of visitors. To be effective, length-of-stay limits must be very low.

COMMENTS

If use of problem areas is reduced substantially, increased use of other areas must be expected and planned for. Stay limits low enough to reduce use effectively also will carry the highest costs for visitors and require the most intensive and costly enforcement by managers.

SOURCES

Parsons (1983).

Strategy II. Reduce Use of Problem Areas

TACTIC 11: MAKE ACCESS TO PROBLEM AREAS MORE DIFFICULT AND/OR IMPROVE ACCESS TO ALTERNATIVE AREAS

PURPOSE

To reduce visitor use of problem areas by shifting some of it to areas that are either better suited for it or little used, through subtly influencing visitors' decisions.

DESCRIPTION

Access can be modified either by maintaining the trails and bridges that provide access to these areas to a lower standard or by improving the quality of trails and bridges that provide access to other places. Bridges over streams could be removed or deliberately not provided. Roads that provide access to trailheads leading to problem areas can be closed or maintained to reduced standards, new roads or trails can be built, and the quality of existing roads and trails that provide access to other places can be improved.

CURRENT USAGE

Infrequent to common. Changes in ease of access are common, but usually access is not altered with the specific intent of manipulating internal use distribution. Improving or building new access roads is about as common as reducing maintenance or closing roads. But upgrading trails or building new trails is two to three times as common as reducing maintenance or closing trails (Washburne and Cole 1983). (Recent budget reductions may have changed this balance.)

COSTS TO VISITORS

Low. Visitors retain freedom of choice about where to go and management presence is subtle. Visitors who are not informed about minimally maintained trails or roads may be exposed to undesirable hazards, however. Some former visitors who return may be displeased by lower standard trails or bridge removal.

COSTS TO MANAGEMENT

Moderate to high. Costs depend on whether most changes involve improving access or reducing maintenance to make access more difficult. Road and trail building or upgrading can be costly. Reduced maintenance can save money, although maintenance to avoid resource damage may still be necessary. Correcting serious damage following a period of neglect can be more expensive than regular maintenance. It is also important to provide up-to-date information on road and trail conditions if use distributions are to change; frequent updating involves some additional costs.

EFFECTIVENESS

This technique could be highly effective if access to problem areas is made sufficiently difficult to reduce use substantially and if information on access conditions is made available to visitors when they are planning a trip. Manipulating access seems particularly appropriate to dealing with problems of wildlife disturbance in specific places.

COMMENTS

As with all techniques under this strategy, the implications of increased use and impact in alternative areas must be considered and planned for. Visitor opinion about the desirability of such actions is divided.

SOURCES

Stankey (1973, 1980), Lucas (1985), Stankey and Schreyer (1987).

Strategy II. Reduce Use of Problem Areas

TACTIC 12: ELIMINATE FACILITIES OR ATTRACTIONS IN PROBLEM AREAS AND/OR IMPROVE FACILITIES OR ATTRACTIONS IN ALTERNATIVE AREAS

PURPOSE	To reduce visitor use of problem areas by shifting some use to areas either better suited for it or lightly used, through subtly influencing visitors' decisions.
DESCRIPTION	The relative attractiveness of problem areas could be reduced through manipulation of facilities and attractions, such as shelters, outhouses, hitch rails, corrals, bridges, signs, and stocked fish. (Manipulating fisheries to modify use in National Forest Wilderness currently is limited by the Policies and Guidelines of the International Association of Fish and Wildlife Agencies accepted by the Forest Service.) Attractiveness can either be reduced in problem areas or increased elsewhere, within the constraints of appropriateness in wilderness.
CURRENT USAGE	Unknown, but probably rare. Removal of facilities, fish stocking, and elimination of fish stocking are all occurring, but such actions are often taken for reasons other than to alter internal use distributions.
COSTS TO VISITORS	Low. Costs are minimal as long as the information that is provided on facilities and attractions is accurate.
COSTS TO MANAGEMENT	Low to high. Costs are incurred in making physical changes and in the preparation and dissemination of information about conditions. Such information may require frequent updating.
EFFECTIVENESS	This technique will be effective only if there is a pronounced shift in the relative attractiveness of areas **and** this change is communicated to visitors. Good communication will both increase the effect of facility changes and cause shifts in use to occur more rapidly. It may be particularly effective in shifting certain types of visitors, such as stock users and novices—visitors who are especially attracted to certain facilities.
COMMENTS	The appropriateness of providing facilities in wilderness for reasons other than visitor safety and resource protection must be considered. A high level of facility development is considered undesirable by most visitors, and it conflicts with the Wilderness Act and wilderness philosophy. Also, facilities may be most desirable, particularly for resource protection, in problem areas. They are probably least appropriate in remote areas. Again, increased use of alternative areas must be planned for. These problems suggest that generally it will be more useful to remove facilities or attractions in problem areas than to build them elsewhere. Facilities may have to be built in problem areas to protect the resource (strategy VII).
SOURCES	Hendee and others (1968), Stankey (1973), Murray (1974), Echelberger and Moeller (1977), Lucas (1980, 1985), Stankey and Schreyer (1987).

Strategy II. Reduce Use of Problem Areas

TACTIC 13: ENCOURAGE OFF-TRAIL TRAVEL

PURPOSE	If more visitors traveled off-trail, trail encounters would obviously be reduced. Crowding and visitor conflict might also be reduced in camping areas reached by trail.
DESCRIPTION	Off-trail travel could be encouraged in low-impact-use brochures and other sources of information, including contacts with wilderness rangers. Maps could identify areas favorable for cross-country travel.
CURRENT USAGE	Unknown, but probably rare.
COSTS TO VISITORS	Low. Costs are minimal as long as the suggestion to travel off-trail is not too value-laden, making some visitors feel guilty for choosing to use trails instead.
COSTS TO MANAGEMENT	Low. The major costs involve deciding where off-trail travel should be encouraged and communicating these recommendations to visitors.
EFFECTIVENESS	This is unlikely to be very effective because few visitors are comfortable traveling off-trail. Moreover, those who do enjoy off-trail travel will usually seek out remote areas on their own. This technique could reduce crowding and conflict in some places. It might increase crowding and cause ecological impact problems away from trails, however.
COMMENTS	Promoting off-trail travel can have a number of negative consequences; visitor hazards and the creation of undesired impromptu trail systems are the most obvious. Off-trail travel by stock can be particularly damaging. Increased disturbance of wildlife is also a possible undesirable side effect. Cross-country travel is fairly easy in some wildernesses but very difficult in others because of steep topography and heavy vegetation. In most situations, a preferable means of reducing use is to discourage use of problem areas (tactic 8).
SOURCES	None.

Strategy II. Reduce Use of Problem Areas

TACTIC 14: ESTABLISH DIFFERENTIAL SKILL AND/OR EQUIPMENT REQUIREMENTS

PURPOSE

If managers require special skills or equipment to enter problem areas, but they do not require them in other areas, use levels in problem areas are likely to be reduced.

DESCRIPTION

Require evidence of skill, such as in minimum-impact camping, through completion of acceptable courses or passing a test, and/or require possession and use of equipment that reduces impact, such as tents with integral poles; camp stoves; tents of subdued, natural colors; high-line hitching ropes for horses; etc. The certificate would be required for visiting specific places (in effect, a permit).

CURRENT USAGE

Apparently untried for purposes of reducing use in problem areas. In some areas, certain skills and equipment are required only on whitewater rivers or for mountain climbers. These requirements are intended to promote safety and minimize impact rather than reduce use.

COSTS TO VISITORS

Low. Costs are significant only for those visitors who are unable or unwilling to meet test or equipment requirements or who feel the test is unfair, **and** who only want to visit problem areas. For others who want to visit the problem areas, costs are the time, effort, and money required to qualify. These costs need not be high relative to those associated with the trip itself. Costs are incurred offsite and during the planning stages of trips. Some required skill or equipment may contribute to more enjoyable trips for visitors.

COSTS TO MANAGEMENT

Moderate to high. Development and administration of skill tests, equipment checks, enforcement, and employee training will all add to costs. Testing skills would usually cost more than checking equipment. The fact that requirements would apply in some places but not in others would increase administrative difficulties. A permit system would be required. Costs will be ongoing. Some skill testing might be done by other organizations, schools, etc., which would lower costs.

EFFECTIVENESS

Could be effective if requirements are so stringent that many potential visitors go elsewhere.

COMMENTS

Unfortunately, special skills and equipment are usually more important in little-used and impacted areas than in places that already have problems. Problem areas are usually the most appropriate places for novices and visitors without low-impact training and equipment. Therefore, this technique usually would be counterproductive.

SOURCES

None.

Strategy II. Reduce Use of Problem Areas

TACTIC 15: CHARGE DIFFERENTIAL VISITOR FEES

PURPOSE	By charging visitors more to enter problem areas, the use of these areas is likely to decline.
DESCRIPTION	Charge a fee to visit problem areas, but not other areas that are either better suited to accommodate use or lightly used. Another option would be to charge higher fees in problem areas than elsewhere. Fees might be per visit or per day in problem areas.
CURRENT USAGE	Apparently untried for purposes of reducing use in problem areas. Fees are charged on a few whitewater rivers, but not to visit adjoining parts of the wilderness. Fees are associated with the need to administer a use limitation program only on the river.
COSTS TO VISITORS	Low. Costs are significant only for those visitors who are unable or unwilling to pay the fee **and** who only want to visit problem areas. Costs to visitors obviously rise as fees increase.
COSTS TO MANAGEMENT	Moderate to high. Costs are associated with fee collection and enforcement; costs would increase with the number of places within the wilderness where fees were charged. The cost/benefit ratio for this technique would depend on the extent to which managing agencies benefited from retaining revenues generated to strengthen management and protection of wilderness.
EFFECTIVENESS	Should be quite effective if fees are high enough to encourage many visitors to go elsewhere.
COMMENTS	Beyond the problem of lack of general authority for charging fees, and particularly differential fees, this technique would have many advantages. Visitor costs are low, particularly if visitors are made aware of fees when planning their trip, and fees are not excessively high. Management costs would not be increased if agencies were allowed to keep the revenues the fees generate and the technique should effectively reduce use of the problem area. The imposition of a fee might make visitors more careful to minimize their impact, although this is uncertain. Some people believe fees can have the opposite effect. It is important, however, to plan for increased use and impact in other places. Acceptability to visitors of fees in general varies from low to high (for example, Stankey 1973; Shelby and others 1982).
SOURCES	Manning and others (1984).

Strategy III. Modify the Location of Use Within Problem Areas

TACTIC 16: DISCOURAGE OR PROHIBIT CAMPING AND/OR STOCK USE ON CERTAIN CAMPSITES AND/OR LOCATIONS

PURPOSE

Both camping and stock use have considerable potential to cause impact. Such impacts could be reduced by discouraging or prohibiting such uses in inappropriate places.

DESCRIPTION

Either discourage or prohibit camping and/or stock use in inappropriate places. Inappropriate places can be those that are particularly fragile or likely to be impacted by use, those that have already been excessively disturbed, or those where use is likely to disturb other visitors. Regulations or suggestions can be applied to specific campsites, larger destination areas, or to classes of sites, such as those close to water or in meadows.

CURRENT USAGE

Common. Many variations on this technique exist. The most widespread are prohibitions on camping and stock use close to water. Camping setbacks from water range from 20 feet to one-half mile; the most common distance is 100 feet. The most common setback for stock is 200 feet; exceptions are made for watering. Camping prohibitions on selected highly impacted campsites are also common, as are prohibitions on camping adjacent to trails and on stock use on certain trails or general areas. Less common are prohibitions on stock in campsites and prohibitions on camping near other campsites, in certain general areas, or in certain ecosystem types such as meadows. Although frequency is unknown, it is common to discourage camping in certain locations (such as close to other camps or trails, close to water, in meadows, on heavily impacted sites, or in heavily used areas). Similarly, it is common to discourage stock use in such locations. Sometimes use is discouraged by obliterating sites, and occasionally by blocking sites with brush or rocks.

COSTS TO VISITORS

Low to high. Costs depend on whether or not regulatory action is taken, the frequency and types of prohibitions, and the attractiveness and availability of alternative use locations. Costs are generally less when regulation is avoided; however, costs can be inequitably borne by conscientious users when use of certain places is discouraged rather than prohibited. Costs increase with the number of closed places and with the value visitors place on camping or using stock in particular locations. Costs also increase if there are few attractive alternative use locations or if visitors are not aware of where such alternatives are located. Costs can be reduced by informing users of prohibitions as early as possible, by providing adequate reasons for closures, and by informing visitors of alternative areas.

COSTS TO MANAGEMENT

Moderate. If relying on visitor compliance with recommended behavior, information must be disseminated. If relying on regulation, information must be disseminated and regulations must be enforced, which raises costs. In both cases, limited signing may be necessary within the wilderness to inform visitors of closures and alternative use locations. Signing at entry points is preferable, and this is usually possible with an easily understood general closure, such as "no camping in meadows."

EFFECTIVENESS

Closures can be an effective means of promoting recovery of "sore spots" or of avoiding damage to particularly rare or valued ecosystems or locations (such as lakeshores). They can also be used to avoid damaging particularly fragile areas, but most closed locations are not really more fragile than locations left open. Prohibiting confinement of stock close to water to avoid water pollution is one example of using this technique to avoid damaging areas particularly prone to impact. Discouraging use of already disturbed sites can be an effective means of avoiding pronounced campsite deterioration—in lightly used places only; this method is counterproductive in heavily used places (Cole and Benedict 1983). Perhaps most frequently, campsites are closed or use of certain types of locations is discouraged to reduce crowding and conflict problems, mainly by making campers less conspicuous and keeping special attractions, such as lakeshores, open for all to use. Effectiveness requires high levels of compliance.

Managers attempting to avoid regulation may want to monitor compliance with suggestions to determine whether regulation is needed or not. In most places, recovery of sore spots will require total elimination of use and assisted rehabilitation (tactic 37); otherwise, long recovery periods will be even longer.

COMMENTS

Closure of campsites or general locations will shift use and impact elsewhere; this should be planned for. Asking visitors to generally not camp on well-impacted sites is likely to promote campsite proliferation, except in places where use levels are very low and visitors are skilled low-impact campers. In the Bob Marshall Wilderness complex, a majority of visitors objected to a regulation prohibiting camping within 200 feet of water (Lucas 1985), and in areas with such regulations, compliance is often poor. Closing some areas to stock use is more generally acceptable (Lucas 1980). Social objectives might be achieved with more specific suggestions to find a campsite screened by trees or topography, and to camp far enough from lakes to avoid monopolizing shorelines.

SOURCES

Parsons (1979), Lucas (1980, 1985), Bultena and others (1981a), Cole (1981a), Roggenbuck and Berrier (1981), Cole and Benedict (1983), Cole and Ranz (1983), DeBenedetti and Parsons (1983), Thornburgh (1986).

Strategy III. Modify the Location of Use Within Problem Areas

TACTIC 17: ENCOURAGE OR PERMIT CAMPING AND/OR STOCK USE ONLY ON CERTAIN CAMPSITES AND/OR LOCATIONS

PURPOSE

Stock and camping impacts can be limited in areal extent if they occur only in certain places. Moreover, if such places are durable, the severity of impact could be reduced further.

DESCRIPTION

This technique is similar to the preceding technique. Instead of identifying campsites or general locations where camping or stock use **is not** appropriate, this technique involves identifying places where such use **is** appropriate. Such a strategy could be implemented by allowing camping or stock use only in certain places. It could also be implemented by asking visitors to camp or use stock only in certain places. Camping or stock use could either be confined to specific designated sites or allowed anywhere within a general area but not outside that area. Regulations or suggestions could apply to camping or stock use or to both.

CURRENT USAGE

Infrequent to common. Requiring visitors to camp on designated sites is infrequent, except in National Parks, where it is a common technique. Designated sites are also used by the Forest Service in such places as the Boundary Waters Canoe Area Wilderness and some southern California wildernesses. Encouraging visitors to camp on previously used campsites is a common practice. Some areas require or ask visitors to camp on designated or previously used sites in certain places, while allowing visitors to camp wherever they want elsewhere. Generally sites are designated in popular areas, while at-large camping is allowed in more remote areas. In National Parks it is common for stock to be allowed only in designated stock camps; however, this restriction is seldom practiced in wildernesses managed by other agencies. Some areas allow stock use only in certain areas or on certain trails; another variation is to allow stock only in traditionally used places. In a few places managers encourage visitors to camp on previously unused sites.

COSTS TO VISITORS

Low to high. Costs depend on the level of regulation, whether or not some places with at-large camping and stock use are also provided, and where camping and stock use opportunities are provided. Costs become high when areas where use is allowed are away from places visitors want to be or where sites are clustered together, eliminating opportunities for campsite solitude. They are also high when confinement of use to selected places is combined with a program requiring visitors to establish a fixed itinerary before entering the area (usually part of tactic 9). The high costs are imposed more by the itinerary, which reduces freedom and spontaneity, than by only being allowed to camp or take stock to certain places. Costs can be reduced by making visitors aware of regulations, reasons for regulations, and alternative opportunities for use while they are planning their trip.

COSTS TO MANAGEMENT

Moderate. If relying on visitor compliance with recommended behavior, information must be disseminated. If relying on regulation, information must be disseminated and regulations must be enforced, with higher costs. Site maintenance costs may also be substantial due to the concentration of use. But this is likely to be offset by the fact that a smaller number of sites require attention.

EFFECTIVENESS

This can be highly effective in avoiding problems with campsite deterioration, packstock impact, human waste, water pollution, trail deterioration, and wildlife disturbance throughout most of the wilderness. It was the most effective of many techniques implemented in order to minimize campsite impacts in a popular lake basin in Glacier Peak Wilderness (Thornburgh 1986). It may result in severe impact problems in certain places because of concentrating use; however, much research suggests that the additional impacts of increased use in popular areas are small. Use concentration may aggravate crowding, however. Wide spacing and screening of designated sites can reduce crowding problems.

COMMENTS

This technique is particularly appropriate in areas of high use and fragility. Although fixed itineraries are strongly disliked by most visitors, attitudes toward designated sites are more positive.

SOURCES

Echelberger and Moeller (1977), Cole (1981a, 1982c), Cole and Dalle-Molle (1982), Cole and Benedict (1983), Echelberger and others (1983), Thornburgh (1986), Marion and Sober (in press).

Strategy III. Modify the Location of Use Within Problem Areas

TACTIC 18: LOCATE FACILITIES ON DURABLE SITES

PURPOSE	A given amount and type of use will cause less impact if that use occurs on a more durable location.
DESCRIPTION	Locate all facilities on durable sites. This would apply particularly to trails, but in certain areas to bridges, agency-built campsites, toilets, and stock-holding facilities. The concept of a durable site can also be extended beyond resource considerations to sites where use is least likely to disturb other visitors' experiences. Thus, managers would attempt to locate facilities in places where (1) physical deterioration is least likely and (2) facilities and parties using them are least obtrusive.
CURRENT USAGE	Unknown, but probably tried, with differing degrees of effort and success, in all areas with facilities.
COSTS TO VISITORS	Low. Costs are negligible except where visitors are required to use facilities and the facilities are not located where visitors want to go.
COSTS TO MANAGEMENT	Low. As long as the facilities would be built anyway, the only additional costs are associated with conducting research into which sites are most durable and then locating sites that meet the criteria established. These costs will be more than offset in the long run by reduced maintenance costs.
EFFECTIVENESS	There is ample evidence that this can be among the most useful techniques for minimizing trail deterioration. Much of the variation in the level of deterioration of neighboring trail segments is a result of differences in site durability. Level of campsite deterioration also differs substantially with factors such as openness of the tree canopy (Marion and Merriam 1985) and vegetation type (Cole 1981b; 1983b). Locating stock-holding facilities away from water effectively reduces the risk of water pollution problems. Routing trails away from areas that wildlife use to feed and breed reduces potential for wildlife impact. Locating facilities in areas with considerable screening and in places where sounds are dampened can reduce problems with crowding. Many other examples of how this technique can effectively reduce problems could also be cited.
COMMENTS	The benefit/cost ratio of this technique is very high, provided that the decision to provide facilities has already been made. Facilities should be justified, of course, as necessary for protecting wilderness resources, not for visitor comfort and convenience.
SOURCES	Dailey and Redman (1975), Helgath (1975), Cole (1981b, 1982a, 1982b, 1983b, 1987).

Strategy III. Modify the Location of Use Within Problem Areas

TACTIC 19: CONCENTRATE USE ON SITES THROUGH FACILITY DESIGN AND/OR INFORMATION

PURPOSE

The areal extent of impact can be reduced by channeling or concentrating use on or within individual sites.

DESCRIPTION

The design and placement of facilities such as shelters, fire grates or rings, toilets, tables, potable water supplies, hitch rails, and corrals, where these are judged to be compatible with wilderness objectives, can be used to channel use. Even the design of access trails between facilities or the placement of discrete barriers can serve to minimize the areal extent of impact. Information about specific facilities and their locations, as well as education about the need to confine impact and not spread out on a site, can also be used to reduce the areal extent of impacts.

CURRENT USAGE

Unknown. Despite the Wilderness Act's definition of wilderness as a place "without permanent improvements," facility development is common. More often facilities are provided to protect resources rather than to channel use. Fireplace grates, toilets, shelters, and stock-holding facilities are most common. Tent platforms are found in some places, and public cabins are provided in some Alaskan wildernesses. Information provided to visitors on the location of facilities ranges from nonexistent to good. In a few areas visitors are informed of the desirability of concentrating use both on a few sites and within sites; other areas consider concentration to be undesirable.

COSTS TO VISITORS

Low. Visitors are neither required nor asked to alter their preferred behaviors. The major cost of facilities is to visitors who consider developed facilities to be inappropriate—a large proportion in many places. Such costs can be minimized by providing facilities only where absolutely necessary and informing visitors of the location of facilities and the reasons they are necessary.

COSTS TO MANAGEMENT

Low to high. Depends on the number and type of facilities provided and the frequency of required maintenance. Information dissemination costs are low and no enforcement is involved.

EFFECTIVENESS

In the Boundary Waters Canoe Area Wilderness, provision of fire grates and toilets, improvement of tent pads, and rehabilitation of areas where unnecessary site expansion is occurring have effectively limited the area of campsite deterioration (Marion and Sober in press). In Great Smoky Mountains National Park, Bratton and others (1978) report less per capita areal impact around shelters than around campsites. Although not documented, stock-holding facilities are highly effective means of minimizing stock impact in places that receive at least moderate levels of stock use. The effectiveness of information alone is untested; we would guess that it would be low to moderate in effectiveness.

COMMENTS

Providing facilities in selected areas is likely to increase use in these areas. It may also encourage more use by novices. This can be either desirable or undesirable but should certainly be planned for. The desirability of facilities should also be considered. Stankey and Schreyer (1987) review visitor preferences for facility development. Generally visitor preferences are mixed; usually the current level of facility development is preferred. If information alone is tried, systematic monitoring would be desirable. Information is noncontroversial and worth trying.

SOURCES

Leonard and others (n.d.), Hendee and others (1968), McEwen and Tocher (1976), Stankey and Schreyer (1987), Marion and Sober (in press).

Strategy III. Modify the Location of Use Within Problem Areas

TACTIC 20: DISCOURAGE OR PROHIBIT OFF-TRAIL TRAVEL

PURPOSE

By encouraging or requiring visitors to stay on trails, use and impact are concentrated along the existing trail system. Areas away from trails remain undisturbed, and unofficial trail systems should not develop.

DESCRIPTION

Restrictions could be in the form of either regulations or suggestions to avoid off-trail travel. They could be applied only to types of use with a high potential for causing impact (such as large parties or parties with stock) or to all visitors. They could also be applied only in certain areas (such as fragile environments or areas of critical wildlife habitat).

CURRENT USAGE

Unknown. Prohibiting or discouraging people from shortcutting switchbacks is a common action. Suggesting that visitors walk in the trail tread rather than on the side of the trail also is a common element of low-impact educational programs. Some areas prohibit off-trail stock use, and a few areas have smaller party size limits for off-trail travelers.

COSTS TO VISITORS

Most visitors use trails and prefer to stick to them (Lucas 1980); for these, costs are negligible. For visitors who do want to travel off-trail, costs are high. Costs can be reduced by providing alternative areas for off-trail use and by informing visitors of restrictions and why they have been imposed.

COSTS TO MANAGEMENT

Low to moderate. Costs involve information dissemination and enforcement if off-trail travel is prohibited. Enforcement of a regulation would be difficult because off-trail visitors would be particularly difficult to locate.

EFFECTIVENESS

As a general policy, it is doubtful that this technique would have much effect. It can be a useful means of avoiding problems caused by particularly destructive types of visitors in currently undisturbed areas. Thus, it may be most useful to discourage or prohibit off-trail travel by certain types of users in certain places.

COMMENTS

Given the difficulty of enforcement, discouragement of off-trail travel is probably preferable to regulation.

SOURCES

None.

Strategy III. Modify the Location of Use Within Problem Areas

TACTIC 21: SEGREGATE DIFFERENT TYPES OF VISITORS

PURPOSE

By separating, in space or time, types of use that typically conflict, crowding and conflict can be reduced, resulting in higher quality visitor experiences.

DESCRIPTION

Separate trails could be provided for each type of visitor, or the less common user that typically "causes" the problem could be banned from certain trails or allowed only in certain places. Common conflicting uses include parties with pets or stock, and exceptionally large parties. Segregation of use could be either regulated or suggested. If the segregation is not symmetrical (for example, if stock are prohibited on certain hiking trails, but hikers are never prohibited on stock trails), then this technique is the same as tactic 16—which could also be applied to large parties and conflicting uses other than stock.

CURRENT USAGE

Unknown. There are places where separate trails are provided for hikers and stock parties, particularly in National Parks. Usually uses are only separated for short distances close to trailheads. It is common to prohibit stock on some trails, and probably there are some areas where pets are not allowed on selected trails.

COSTS TO VISITORS

Low to high. Costs increase as increasing numbers of visitors are prohibited from visiting more places. Costs can be reduced by providing desirable use locations for all groups and by making information available during the early stages of trip planning.

COSTS TO MANAGEMENT

Low to moderate. Primary costs are dissemination of information and enforcement, with higher costs. Additional trails and other facilities may be needed.

EFFECTIVENESS

This can be highly effective in reducing visitor conflict.

COMMENTS

A major difficulty is in making certain that each type of visitor is treated fairly. Segregation of uses may require greater facility development, which may be undesirable. Education to reduce objectionable behavior (tactics 25 and 26) and to increase acceptance by other visitors (tactics 32 and 33) may be worthwhile alternatives.

SOURCES

West (1982).

Strategy IV. Modify the Timing of Use

TACTIC 22: ENCOURAGE USE OUTSIDE OF PEAK USE PERIODS

PURPOSE

In many areas, visitor use is highly concentrated in time—during certain seasons, on weekends, and on holidays. This can create serious crowding problems at these times, even though such problems are minimal at other times. The severity of crowding problems could be reduced if some use could be shifted to less popular times of the week or year.

DESCRIPTION

Under strategies I and II, we described techniques for reducing use either in the entire wilderness or in selected problem areas. This technique involves shifting the timing of use, without either spatial shifts or a reduction in total use. The advantages of visiting the area outside of peak use periods can be advertised, usually with data on the current distribution of use at different times and availability of campsites. This could be geared to calendar dates or seasons and/or weekdays vs. weekends. Efforts to encourage off-season use might point out other possible advantages besides lower use, such as fewer biting insects, fall color, and so on. Brochures, information on maps, and news releases are some specific tools that could be used.

CURRENT USAGE

Unknown. Quite a few National Parks and concessionaires within parks have been advertising the advantages of off-season visits. For this and other reasons, the concentration of use in summer has declined in a number of wildernesses. Brochures and other information sources commonly suggest taking midweek trips, when use levels are lower than on weekends.

COSTS TO VISITORS

Low. Visitors can react as they will to information provided. Any effect on their decisions occurs offsite, during the planning stages of trips.

COSTS TO MANAGEMENT

Low. Information must be prepared in a fashion that convinces some visitors to shift the timing of their trips.

EFFECTIVENESS

In many areas, the timing of use is concentrated by a short, "comfortable" use season, opening dates of fishing and hunting seasons, and such factors as the area's proximity to sources of visitors. Areas that are far from populated areas are likely to experience less pronounced peaks of use on weekends and holidays. This technique may not be effective in remote areas with a short, comfortable use season. Where there seems to be a chance to shift the timing of use, this technique can be a low-cost partial solution to crowding problems.

COMMENTS

Shifting some use from weekends to midweek is unlikely to have undesirable side effects. In some situations, however, resources are particularly fragile during off-seasons (for example, wildlife may be more prone to disturbance or soils may be water saturated). This possibility must be considered when attempting to shift use to low-use seasons. Another factor to consider is the acceptability of increased crowding during off-seasons. Visitors seeking high levels of solitude may already be using off-season periods, and they may be negatively affected by increased use during these periods.

SOURCES

Manning and Powers (1984).

Strategy IV. Modify the Timing of Use

TACTIC 23: DISCOURAGE OR PROHIBIT USE WHEN IMPACT POTENTIAL IS HIGH

PURPOSE

Resource fragility varies between seasons. The same amount and type of use can have very different effects during different seasons, particularly on the severity of wildlife disturbance, trail and campsite deterioration, and packstock impacts. Reducing use during times of high-impact potential can limit impacts.

DESCRIPTION

Limit or avoid all use or certain types of use during particularly sensitive periods. This could either be regulated or suggested. Dates could be standardized or vary, based on specific conditions each year related to soil moisture, stage of plant growth, and so on.

CURRENT USAGE

Rare. A few areas prohibit stock use in the spring and early summer when soils are saturated with snowmelt water and, consequently, are unusually fragile. Other areas have seasonal closures where conflict with wildlife is likely to be detrimental.

COSTS TO VISITORS

Low to moderate. Costs will be low as long as the number of closed areas is low and there are attractive alternative areas to visit. Costs can be minimized by increasing the predictability of closed seasons, providing advance information, and explaining the rationale behind closures. Visitors who have preferred times for visits during critical periods can bear high costs. This might include some hunters in the fall or early-season anglers.

COSTS TO MANAGEMENT

Moderate. Costs include dissemination of information and enforcement. Costs should usually include monitoring of conditions to assess whether closures are really necessary and when they should be in effect. The timing of closures may differ from year to year. DeBenedetti and Parsons (1983) describe a system of seasonal stock closures, the timing of which can be adjusted to compensate for year-to-year differences in moisture.

EFFECTIVENESS

Where variation in fragility from season to season is high and significant amounts of use occur during fragile seasons, this technique can be highly effective. Moreover, costs to most visitors would be low, although some types of use could be eliminated.

COMMENTS

None.

SOURCES

Bultena and others (1981a), DeBenedetti and Parsons (1983), Cole (1987).

Strategy IV. Modify the Timing of Use

TACTIC 24: CHARGE FEES DURING PERIODS OF HIGH USE AND/OR HIGH-IMPACT POTENTIAL

PURPOSE	Fees could be used as a vehicle to reduce use during either high-use or fragile periods of time.
DESCRIPTION	Fees could be charged to visitors only during periods when impact potential is high or, if fees are charged at other times, they could be higher during fragile seasons. Problems with the current lack of authority for charging fees described for tactics 5 and 15 apply here as well.
CURRENT USAGE	Rare. On some whitewater rivers, managers charge visitors only during high-use seasons.
COSTS TO VISITORS	Low. Costs are significant only for those visitors who are unable or unwilling to pay the fee **and** who must visit the area during periods when fees are assessed. Such visitors are probably relatively uncommon.
COSTS TO MANAGEMENT	Low to high. Costs associated with fee collection and enforcement would be offset if managing agencies could retain revenues generated.
EFFECTIVENESS	This technique could be quite effective if the fees charged were high enough to encourage many visitors to avoid high use or fragile seasons.
COMMENTS	Visitor acceptability was moderately high in one hypothetical test. Visitors most readily accept fees known to be devoted to protection and management of the area visited. Legal authority is not now available.
SOURCES	Shelby and others (1982).

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 25: DISCOURAGE OR PROHIBIT PARTICULARLY DAMAGING PRACTICES AND/OR EQUIPMENT

PURPOSE

To reduce impacts by discouraging or prohibiting visitors from taking particularly damaging actions.

DESCRIPTION

Certain practices and equipment are both unnecessary and severely damaging. Simple examples include carving on trees and littering. Although usually unnecessary, axes are often used to damage trees. Other practices, such as building campfires, are particularly damaging in some situations but not in others. Managers can reduce or eliminate such damage by establishing regulations or a set of suggested practices.

CURRENT USAGE

Common. This is the most widespread specific wilderness management technique. A majority of areas have both informational materials that discourage certain practices and regulations that prohibit others. Such programs vary considerably in the number and types of actions that are either discouraged or prohibited. Some of the most common discouraged or prohibited practices are having campfires, littering, cutting trees, shortcutting switchbacks, confining stock in ways that cause impact, disposing of human waste improperly, and washing in lakes or streams.

COSTS TO VISITORS

Low to high. Costs depend on the subtlety and degree of regulation used to change visitor behavior, as well as the importance to visitors of the practices they are being asked to forego. The highest costs are associated with regulation, because visitors lose their freedom of choice. Even without regulation, however, visitor costs can be high if managers aggressively try to change visitor behavior. This is particularly true if the contact with a ranger occurs within the wilderness. Costs also increase as visitors are asked or required to give up practices they consider important to their experience (such as campfires for many visitors). Costs to visitors can be reduced substantially by providing good reasons for regulations/suggestions, by communicating regulations/suggestions to visitors during the planning stages of trips and, where possible, by providing alternative areas where damaging but reasonable practices (such as campfires) are permissible.

COSTS TO MANAGEMENT

Moderate to high. Regulation requires effective communication of regulations and adequate enforcement. Enforcement costs can be quite high. Costs with persuasive techniques are usually lower. The principal costs are associated with deciding on what practices should be discouraged and in developing written materials and the communication skills of wilderness rangers. With both regulation and persuasion considerable effort should be invested in deciding which practices should be prohibited or discouraged and in which specific situations a given practice is either appropriate or inappropriate.

EFFECTIVENESS

Neither regulations nor low-impact information have been studied enough to determine their effectiveness. There is considerable evidence that the pack-it-in, pack-it-out antilitter campaign has been quite successful. Effectiveness can be increased by providing good reasons for regulations or suggestions, by communicating these to visitors during the planning stage of trips, and by providing alternative areas where damaging but reasonable practices are permissible. Most managers believe that personal contact is more effective in changing visitor behavior than written materials. Research on the effectiveness of different approaches to education and information is scarce, but some of it suggests that written material can be almost as effective in some situations (Roggenbuck and Berrier 1981). Enforcement can be important to increasing the effectiveness of regulations. Dalle-Molle (1979) and Parsons (1983) describe the success of programs that restrict certain practices in Mount Rainier and Kings Canyon National Parks, respectively.

COMMENTS

Lucas (1982) provides a step-by-step procedure for deciding whether to use regulations or education.

SOURCES

Bradley (1979), Fazio (1979), Lucas (1980), Bultena and others (1981a), Fazio and Gilbert (1981), Martin and Taylor (1981), USDA Forest Service (1981), Cole and Dalle-Molle (1982), Hammitt (1982), Lucas (1982), Cole and Benedict (1983).

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 26: ENCOURAGE OR REQUIRE CERTAIN BEHAVIOR, SKILLS, AND/OR EQUIPMENT

PURPOSE

To reduce the impact of recreational use by encouraging or requiring behavior, skills, and/or equipment unlikely to damage resources.

DESCRIPTION

This technique is similar to the preceding technique. It could be called the "flip side." Instead of a concern with what visitors **should not** do, this technique is concerned with what visitors **should** do to reduce impacts. Many low-impact education programs focus primarily on encouraging visitors to behave in ways that minimize impact. Managers can also require visitors to possess certain skills and equipment that can be used to reduce impact. This can reduce per capita impacts, as well as total use (tactic 4) and use of problem areas (tactic 14). This is comparable to requiring drivers to have a license and a vehicle that meets safety standards. These skills and equipment could be required only when visiting places that are particularly vulnerable to impact, such as remote off-trail areas or places where wildlife disturbance is likely.

CURRENT USAGE

Rare to common. The encouragement of low-impact behavior is common. Equipment requirements are infrequent, and skill requirements are rare. Requirements are more commonly implemented for this purpose than as a rationing tool. They are most common on whitewater rivers, where use of rafts makes it relatively easy to transport low-impact equipment such as fire pans and portable toilets. Stock users could be subject to similar requirements.

COSTS TO VISITORS

Low to moderate. Costs are significant only for those who are unable or unwilling to meet skill or equipment requirements. There is little reason why many people should fall into this category. For others, the only costs are the time, effort, and money required to qualify. Costs are incurred offsite and during the planning stages of trips.

COSTS TO MANAGEMENT

Moderate to high. Costs include development and administration of information, skill tests, inspection of equipment, and enforcement, depending on which specific techniques are used. Regulation will cost more than education, and skill testing could be particularly expensive. If other organizations, schools, etc., could administer tests, costs could be lower.

EFFECTIVENESS

Equipment requirements on rivers have been very effective in reducing campfire impacts and human waste problems (Carothers and others 1984). Skill requirements could also be effective in increasing use of low-impact techniques; this could help reduce most problems. This technique could be particularly effective in minimizing deterioration of places that are currently relatively undisturbed. The effectiveness of low-impact education has not yet been evaluated systematically, but its potential seems great.

COMMENTS

Versions of this technique could be devised that would require special skills and/or equipment only for certain visitors (for example, stock users or those who want to build fires), in certain places (for example, fragile or currently undisturbed places), or at certain times (for example, during winter when wildlife is particularly vulnerable to disturbance).

SOURCES

Wagar (1940), Stankey and Baden (1977), Muth and Clark (1978), USDA Forest Service (1981), Carothers and others (1984).

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 27: TEACH A WILDERNESS ETHIC

PURPOSE	To contribute to changes in visitor behavior that reduce social and resource impacts of wilderness recreational use. May also result in visitors applying minimum impact practices with better judgment in varying situations as a result of a deeper understanding of overall purposes and values of wilderness.
DESCRIPTION	Teaching a wilderness ethic stresses the philosophy of wilderness values and individual responsibility in relation to these values. It should motivate wilderness visitors to change their behavior and adopt specific minimum impact practices. It focuses on the "why," the foundation for careful wilderness use, in contrast to the "what" and "how" of tactics 25 and 26. It takes time to instill an ethic. Therefore, the opportunities for ethics education must often be provided away from the wilderness.
CURRENT USAGE	Unknown, but probably infrequent except for abbreviated treatment. Teaching a wilderness ethic seems less common than educational programs focused more narrowly on recommended visitor behavior.
COSTS TO VISITORS	Low. The only cost is in time spent in the educational process. Hopefully, such costs should be more than offset by an improved appreciation and understanding of wilderness, as well as pride in having mastered improved skills in minimizing impact. Costs usually are incurred off-site and there is minimal pressure on the visitor to behave in any certain way.
COSTS TO MANAGEMENT	Low to moderate. Costs involve developing educational materials and providing educational opportunities. Because a wilderness ethic is relatively general, costs of developing materials can be shared widely. If educators can be persuaded to present classes on wilderness ethics, even the costs of educating visitors can be low.
EFFECTIVENESS	Although never evaluated, there is much to suggest that this approach has considerable potential. Wilderness visitors tend to be highly committed to the idea of wilderness. They also tend to be highly educated; therefore, they are likely to understand relatively complex subjects and to adjust their behavior accordingly. This technique attacks all problems directly and has low costs for both visitors and managers. Positive benefits from this technique will not be immediate, however, because there usually will be a lag period between education, behavioral changes, and resultant effects on the resource.
COMMENTS	Educational programs have been developed for grade school students and college students, although most programs focus narrowly on specific low-impact practices. More work is needed on both the curriculum of educational programs and how to effectively teach people.
SOURCES	Echelberger and others (1978), Bradley (1979), Fazio (1979), Martin and Taylor (1981).

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 28: ENCOURAGE OR REQUIRE A PARTY SIZE AND/OR STOCK LIMIT

PURPOSE

Large parties are a source of conflict, with many visitors considering them to be inappropriate and undesirable. There is also some evidence that large parties cause more ecological impact (for example, they are more likely to create large campsites) than many small parties. A party size limit, without reducing total use, would reduce certain problems.

DESCRIPTION

Either encourage visitors to keep parties small, with suggestions about desirable maximum sizes, or establish and enforce a specific maximum party size.

CURRENT USAGE

Common. This is one of the most widespread regulations in wilderness. Although usually a regulation, there are probably some areas where limits are encouraged but not required. Established party size limits range from 5 to 60; the most common limit is 25. Limits between 5 and 50 have been established for packstock; the most common limit is 20. Some places have established more stringent limits for more vulnerable places such as off-trail areas.

COSTS TO VISITORS

Low. Most parties are small. Median size is usually around three; in nine western areas, only about 6 percent of all parties were larger than 10 persons (Lucas 1980). Thus, relatively few visitors would pay any costs, even with a limit as stringent as 10 people. Costs are high for those visitors who prefer or must travel in large parties (such as outfitted or organized groups). Such costs might be reduced by permitting use by large groups under special conditions (for example, if they obtained special permits and/or visited specific locations, or had special skills or equipment that reduced their impact). Informing visitors of limits during trip planning is critical to maintaining low costs to the visitor.

COSTS TO MANAGEMENT

Low to moderate. Information about limits must be disseminated and regulations must be enforced. Any special provisions for oversized groups must be established and administered.

EFFECTIVENESS

Should be very effective in reducing one source of visitor dissatisfaction—encounters with large groups—if the limit is low enough. Effectiveness in reducing ecological problems may be less dramatic than many assume. This is particularly true where limits are high, as they usually are. The importance of a limit on party size to minimizing resource damage is greatest where impact is likely to occur quickly. Thus, limits are most important in fragile areas, in little-used and relatively undisturbed areas, and where parties travel with stock.

COMMENTS

It is possible that a party size limit could reduce the number of parties if larger parties go elsewhere. On the other hand, a reduction in party size might increase the number of parties in some areas. Present knowledge is inadequate to predict which outcome is more likely. There can also be a problem with large parties that split into several smaller groups to comply with the party size limit but then rejoin within the wilderness. Visitor acceptability of party size limits is generally high. Selecting a specific number for a party size limit requires judgment. No formula exists to calculate an ideal number. The situation is parallel to setting speed limits. In our opinion, however, party size limits larger than about 10 persons seem unlikely to have much positive benefit. (As noted earlier, provisions for allowing larger parties under special circumstances may be desirable.)

SOURCES

Lime (1972), Stankey (1973, 1980), Lucas (1980), Roggenbuck and others (1982), Cole (1987), Stankey and Schreyer (1987).

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 29: DISCOURAGE OR PROHIBIT STOCK

PURPOSE	Generally, stock cause more impact—both social and ecological—than humans (Cole 1987; Stankey and Schreyer 1987). Limiting or eliminating stock use will reduce many types of problems. On the other hand, it will also eliminate or reduce opportunities for a traditional use of wilderness that some visitors value highly.
DESCRIPTION	Either use a variety of communication techniques to persuade visitors to not use stock or establish and enforce a regulation prohibiting stock.
CURRENT USAGE	Rare. Only a few wildernesses prohibit stock use. Prohibition of stock in certain parts of the wilderness (discussed in more detail under tactic 16) is common, however. It is unknown how many areas discourage stock use; this is probably rare.
COSTS TO VISITORS	Low to high. Costs depend on the number of visitors affected. Overall costs are low because few wilderness areas have much use by packstock. Costs to stock users would be very high, however, and overall costs could be high in those areas with considerable stock use. Such costs could be reduced by allowing stock use in some parts of the area or by providing opportunities elsewhere for recreation with stock of a similar kind and quality.
COSTS TO MANAGEMENT	Low to high. In many places the political costs of such an action would be extremely high. Outfitters offering horseback trips would be eliminated if stock use was prohibited. Other costs include dissemination of information and enforcement. Such costs would be offset by less need for facility development and maintenance, particularly of trails.
EFFECTIVENESS	This tactic would be highly effective in dealing with packstock impacts on the environment and visitor experience. Again, this benefit must be weighed against the high cost of lost recreational opportunities for stock users.
COMMENTS	Increased stock use in other places where stock use is not discouraged or prohibited must be considered. Selective prohibitions on stock will generally be more easily defended than a complete ban. Visitors tend to accept closing some areas to horses, even in areas that receive a considerable amount of horse use. Wilderness-wide prohibitions on horse use were less acceptable in one study (Hendee and others 1968). Adoption of low-impact horse use techniques (tactics 25, 26, and 27) and efforts to modify hikers' attitudes about horses (tactics 32 and 33) could also help avoid limitations on stock.
SOURCES	Hendee and others (1968), Stankey (1973), Lucas (1980), Cole (1987).

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 30: DISCOURAGE OR PROHIBIT PETS

PURPOSE

Pets can be considered unnecessary to the wilderness experience, and they can have a significant impact on wildlife and other visitors. Dogs can carry *Giardia*, but so do many other animals and people. Prohibiting or discouraging pets will reduce these impacts. On the other hand, it will also eliminate opportunities for a traditional use of wilderness that some visitors value highly.

DESCRIPTION

Either use a variety of communication techniques to persuade most visitors to not bring pets, particularly dogs, which are the primary concern, or establish and enforce a regulation prohibiting them.

CURRENT USAGE

Common. Pets are prohibited in National Park wilderness. They are rarely prohibited in wildernesses managed by other agencies, although managers of more and more areas discourage visitors from bringing pets, dogs in particular.

COSTS TO VISITORS

Low to high. Costs depend on the number of visitors affected. Although few data are available, parties with pets are probably more common in most wilderness areas than parties with stock; they are still a minority, however. Costs to visitors who travel with pets would be high. Some of them visit National Forest wildernesses because they cannot travel with their dogs in National Parks. Costs could be particularly high for visitors who travel alone and enjoy the companionship of a pet; this is particularly significant for women traveling alone who bring a dog, in part, for protection. Such costs could be reduced by allowing pets in certain parts of the area or by providing opportunities for recreation with pets of a similar type and quality outside the wilderness. Asking visitors not to bring pets retains freedom of choice, but it may make certain visitors feel guilty about bringing pets and place most of the cost on conscientious visitors.

COSTS TO MANAGEMENT

Low to moderate. Political costs would generally be less than with attempts to prohibit stock use, despite the probability that a larger clientele would be affected. Principal costs involve dissemination of information and enforcement if a regulation is established.

EFFECTIVENESS

While a prohibition on pets is likely to largely eliminate problems with pets, there is little evidence that pets cause substantial problems. Observations suggest that asking people not to bring pets is less effective than a prohibition.

COMMENTS

Generally, pets could be allowed but prohibited in places where or at times when wildlife disturbance is likely or in places where visitors who dislike dogs or other pets could go and not meet parties with them. This option is probably more easily defended than a complete ban.

SOURCES

None.

Strategy V. Modify Type of Use and Visitor Behavior

TACTIC 31: DISCOURAGE OR PROHIBIT OVERNIGHT USE

PURPOSE

A prohibition on camping would obviously reduce camping impacts; it would also reduce other problems. On the other hand, it dramatically reduces recreational opportunities in the area.

DESCRIPTION

Camping could be prohibited by establishing and enforcing a regulation, or visitors could be discouraged from camping. This could apply in the entire wilderness or just in certain problem areas.

CURRENT USAGE

Infrequent. It is common in areas administered by the Fish and Wildlife Service, however. The most common reason for a ban on camping is to avoid wildlife disturbance. This action almost always involves prohibiting rather than discouraging camping.

COSTS TO VISITORS

High. Typically, about half of the parties entering wilderness are day-users; these visitors would incur no costs. Costs would be very high for those wanting to camp. Limiting closures to parts of the wilderness and providing alternative areas where camping is allowed are means of reducing costs where closures are necessary. Effectively communicating information about and reasons for closures is important.

COSTS TO MANAGEMENT

Moderate. Costs would be incurred in the dissemination of information and enforcement of regulations.

EFFECTIVENESS

This should be a highly effective way to reduce problems on campsites. Most other problems, except perhaps trail deterioration, should also be alleviated to some extent. Given the importance of what visitors are asked to forego, merely asking visitors not to camp is unlikely to be effective and probably places responsibilities unfairly on conscientious visitors.

COMMENTS

Wilderness-wide bans on camping reduce recreational opportunities so severely that they should be considered only where the resource is highly fragile, unique, and in need of exceptionally strong protection. Eliminating camping contradicts definitions of wilderness by many of its founders, including Aldo Leopold and Bob Marshall, and much of the philosophy of wilderness. Bans in selected places are more reasonable and were covered in more detail under tactic 16.

SOURCES

None.

Strategy VI. Modify Visitor Expectations

TACTIC 32: INFORM VISITORS ABOUT APPROPRIATE WILDERNESS USES

PURPOSE

One of the primary sources of visitor conflict occurs when visitors encounter uses that they consider to be inappropriate in wilderness. If visitors are aware of which uses are legally appropriate, they are likely to react less negatively when encountering a type of use that they would rather not encounter but that is legally appropriate.

DESCRIPTION

Visitors can be informed about appropriate uses through educational programs, written material, and personal contacts. Appropriateness can be defined in terms of both visitor preferences and legal definitions. The legal status of commodity uses, such as livestock grazing, mining, or water storage, could be explained. So could the appropriateness and legality of various types of recreational use that some visitors may not prefer, such as horseback riding or mechanized travel (in a few places).

CURRENT USAGE

Unknown. Use of this technique is increasingly common; more and more areas are developing educational programs that go beyond the mere "do's and don'ts" of low-impact use.

COSTS TO VISITORS

Low. Management presence is subtle and occurs offsite. Visitors are not asked to change their behavior, so costs are negligible.

COSTS TO MANAGEMENT

Low. Costs are incurred in developing educational materials and providing educational opportunities. Because many areas have the same appropriate uses, the costs of developing materials can be shared widely.

EFFECTIVENESS

Although never evaluated, such a program should be effective in reducing conflict.

COMMENTS

Informing visitors of appropriate uses should be an integral part of either teaching a wilderness ethic or encouraging low-impact behavior and skills (tactics 26 and 27). There are virtually no visitor costs and additional management costs are minimal. Promoting better understanding of other types of use (especially horse-hiker relations) seems important. Finding ways of communicating to hikers the importance of the horse use tradition and how much it means to many horse users will be a challenge.

SOURCES

Stankey and Schreyer (1987).

Strategy VI. Modify Visitor Expectations

TACTIC 33: INFORM VISITORS ABOUT CONDITIONS THEY MAY ENCOUNTER IN THE WILDERNESS

PURPOSE	By informing visitors about which parts of the wilderness are crowded, which are used by recreational stock, which provide certain recreational experiences, and so on, visitors could avoid situations they do not like and not be surprised by conditions they did not expect to find. Beyond conditions related to recreation use, this can also apply to such conditions as the presence of dams or sheep and cattle grazing. By modifying visitor expectations so that they fit better with conditions they are likely to encounter, problems with crowding and conflict should be reduced.
DESCRIPTION	Visitor information and education programs can provide this information, using a variety of communication techniques. Some conditions (such as the presence of certain types of uses) or permanent features (such as dams) can be described on maps and in brochures. More detailed information (such as where bands of sheep are grazing) will need to be updated, perhaps by inexpensive, small handout maps or notes on maps in ranger stations.
CURRENT USAGE	Unknown. Quite a few areas provide highly selective information, but few areas provide very complete information of this type.
COSTS TO VISITORS	Low. Costs would increase if the information provided was inaccurate or biased in an attempt to get visitors to behave in a certain way.
COSTS TO MANAGEMENT	Low to moderate. Costs involve some monitoring of conditions, selection of information to be presented, and dissemination of this information. It is best to get information to visitors during the planning of trips so that they can plan accordingly.
EFFECTIVENESS	This should be an effective means of reducing visitor crowding and conflict. Visitors may still encounter situations they do not like, but they should not be surprised and they freely chose to visit the area. At some point, however, visitors will be dissatisfied with conditions whether they know about conditions in advance or not. At that point, additional management actions will be needed.
COMMENTS	If provision of such information results in pronounced shifts in the distribution of use, this may have to be managed. Visitor interest in information of wilderness use and conditions is high.
SOURCES	Lime and Lucas (1977), Echelberger and others (1978), Bultena and others (1981b), Lucas (1981), Roggenbuck and Berrier (1981), Krumpe and Brown (1982), Shelby and others (1983).

Strategy VII. Increase the Resistance of the Resource

TACTIC 34: SHIELD THE SITE FROM IMPACT

PURPOSE

The same amount and type of use will cause less impact if the durability of the site can be increased. We already described decreasing impacts by directing use to durable locations. Tactics under this strategy increase the durability of a given site. One means of increasing durability is to artificially separate visitors from the resource, thus shielding the site from visitor impact.

DESCRIPTION

Shield sites by constructing facilities, including bridges, turnpikes, and "corduroy" on trails, and tent platforms on campsites. Although toilets and shelters primarily serve to concentrate human waste and camping use (tactic 19), they can also be considered a means of shielding the site. Facilities need to be compatible with wilderness goals and definitions. This tactic should be focused on resource protection, not visitor comfort or convenience.

CURRENT USAGE

Rare to common. Actions to shield trails are extremely common. Toilets are less widespread and shelters even less so, but both are still common. Raised tent platforms are rare.

COSTS TO VISITORS

Low to moderate. Costs depend on the obtrusiveness of facilities and visitor preferences. Generally visitors appear to be more accepting of trail development than of campsite development (Stankey and Schreyer 1987). Visitor costs can be reduced by explaining the need for shielding measures to increase visitor understanding.

COSTS TO MANAGEMENT

Moderate to high. Costs depend on the facilities required and the number of sites that must be shielded. Costs are lowest when sites are shielded before they deteriorate. Both construction and maintenance costs need to be considered.

EFFECTIVENESS

This is one of the most effective means of avoiding trail deterioration problems. Unless the trail can be relocated to a durable site (tactic 18), deterioration of muddy stretches, in particular, can be avoided only through bridging of some type. This technique is less effective in avoiding other types of problems.

COMMENTS

The benefits of shielding, in terms of resource protection, must be weighed against the costs of obtrusive structures. (The cure may be worse than the problem!) The relative appropriateness of strengthening, in which conditions are purposely altered (the next technique), and shielding, in which structures protect conditions, must also be considered. Toilets and shelters may concentrate use undesirably and result in social and resource impacts.

SOURCES

Leonard and others (n.d.), Hendee and others (1968), Stankey (1973), Murray (1974), Proudman (1977), Leonard and Plumley (1979), Lucas (1980).

Strategy VII. Increase the Resistance of the Resource

TACTIC 35: STRENGTHEN THE SITE

PURPOSE	Strengthening techniques involve changing soil and vegetation conditions (and possibly also wildlife behavior) such that they become more resistant.
DESCRIPTION	Take actions to strengthen sites consistent with wilderness goals and definitions. Examples would include using soil cement, water bars, or steps on trails; watering, fertilizing, or planting resistant turf grasses; or opening up the tree canopy to encourage growth of resistant grasses on campsites. Some authors have also discussed attempting to habituate wildlife to encounters with humans so that they are less vulnerable to disturbance, as has occurred with certain unhunted species in National Parks (Ream 1979).
CURRENT USAGE	Rare to common. A few trail design techniques, particularly water bars, are standard practices in wilderness. Most other techniques are rare. Because natural soil and vegetation conditions are purposely altered, most site-strengthening techniques are considered inappropriate in wilderness, although they are standard on more developed recreation sites.
COSTS TO VISITORS	Low to moderate. Costs depend on the obtrusiveness of techniques and visitor preferences. Generally visitors more readily accept trail development than campsite development (artificial site manipulation to protect resources) (Stankey and Schreyer 1987). Costs can be reduced by explaining the need for strengthening measures.
COSTS TO MANAGEMENT	Moderate to high. Costs depend on the actions required and the number of sites that must be strengthened. Costs are lowest when sites are strengthened before they deteriorate.
EFFECTIVENESS	This tactic can be highly effective in handling certain types of problems, particularly excessive trail erosion.
COMMENTS	As with shielding, the benefits of resource protection must be weighed against the costs of purposeful and often visually obtrusive alteration of natural conditions. Introducing nonnative species is particularly undesirable.
SOURCES	Leonard and others (n.d.), Proudman (1977), Leonard and Plumley (1979).

Strategy VIII. Maintain or Rehabilitate the Resource

TACTIC 36: REMOVE PROBLEMS

PURPOSE	Instead of attacking the cause of problems, it is possible to deal with problems through rehabilitation after they occur. One type of rehabilitation involves removing problems from the wilderness.
DESCRIPTION	Remove unacceptable evidence of human use. Primary examples are collection and removal of litter and human waste. Exotic plants and animals and unauthorized facilities could also be removed.
CURRENT USAGE	Common. Rangers remove litter from most areas. Removal of human waste from vault toilets is infrequent.
COSTS TO VISITORS	None.
COSTS TO MANAGEMENT	Moderate to high. Costs depend on the volume of material that must be removed and the extent to which removal is just a normal part of ranger patrols. Most areas that utilize toilets use pit toilets and waste is not removed from the area. Help from volunteers and visitors can be enlisted for dealing with litter removal.
EFFECTIVENESS	This technique can be highly effective in dealing with litter and human waste problems. Litter removal will be costly unless visitors are also persuaded not to litter.
COMMENTS	Needs to be supported by programs to change behavior, types of use, or use patterns.
SOURCES	Leonard and others (n.d.), Muth and Clark (1978), Marion and others (1986).

Strategy VIII. Maintain or Rehabilitate the Resource

TACTIC 37: MAINTAIN OR REHABILITATE IMPACTED LOCATIONS

PURPOSE	To maintain or rehabilitate places that have been damaged by human use.
DESCRIPTION	Both trails and campsites can either be maintained and improved while in use or closed and rehabilitated. Trails can be rebuilt, drainage improved, eroded material replaced, etc. Campsites can be seeded or receive transplants, have rocks and logs replaced, soil added or organic material restored, and so on.
CURRENT USAGE	Common. Trails are maintained in essentially all wildernesses. Few areas maintain campsites, other than to clean up and dismantle fire rings—a very common practice—or to remove litter (tactic 36). Assisted rehabilitation of closed trails and campsites is infrequent, but becoming increasingly common.
COSTS TO VISITORS	Low. Costs are incurred only when a favorite site is closed. This cost can be offset by providing attractive alternative sites that can readily be found and by providing clear reasons for the closures.
COSTS TO MANAGEMENT	Moderate to high. Costs depend on the number of trails or sites that must be maintained or rehabilitated. Many areas have used volunteers to reduce costs.
EFFECTIVENESS	This technique can be effective, at least in the long term, but problems will recur unless the causes of problems are also dealt with. In many situations rehabilitation will require very long periods of time.
COMMENTS	Ongoing maintenance of both trails and campsites may be necessary, particularly where use levels are high. It would be best to develop a strategy for avoiding trail and campsite deterioration problems **before** investing in a program of closure and rehabilitation (refer to other tactics for dealing with trail and campsite deterioration problems).
SOURCES	Proudman (1977), Ittner and others (1979), Cole and Schreiner (1981), Cole and Dalle-Molle (1982), Cole (1987), Marion and Sober (in press).

CONCLUSIONS

In conclusion, we would like to reiterate the following points:

1. When trying to decide on a means of dealing with management problems, there is no substitute for careful identification of specific problems and analysis of the situation in which they occur. Peterson and Lime (1979) and Lucas (1982) provide useful guidelines for such an analysis.

2. There are always many alternative means of dealing with a specific problem. All alternatives should be considered. In most cases, a combination of approaches is likely to be most successful. Usually the most suitable techniques will be those that maximize effectiveness and minimize costs, particularly to the visitor.

3. As Manning (1979) points out, many techniques have multiple benefits; they can also have unwanted side effects. A thorough consideration of all the likely effects of a specific technique will maximize benefits and minimize unwanted effects.

REFERENCES

Behan, R. W. Police state wilderness: a comment on mandatory wilderness permits. Journal of Forestry. 72: 98-99; 1974. (Argues that mandatory permits are an unnecessary loss of freedom.)

Bradley, Jim. A human approach to reducing wildland impacts. In: Ittner, R.; [and others], eds. Recreational impact on wildlands. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 222-226. (Describes a comprehensive program for educating users and the general public about wilderness ethics and low-impact visitor behavior implemented by the Eagle Cap Wilderness.)

Bratton, Susan Power; Hickler, Matthew G.; Graves, James H. Visitor impact on backcountry campsites in the Great Smoky Mountains. Environmental Management. 2: 431-442; 1978. (Contains data on the condition of campsites and how condition relates to environmental conditions, amount of use, type of use, and whether the site is a shelter or not.)

Bratton, Susan Power; Hickler, Matthew G.; Graves, James H. Trail erosion patterns in Great Smoky Mountains National Park. Environmental Management. 3: 431-445; 1979. (Contains data on the condition of trails and how condition relates to environmental conditions, trail slope and orientation, and amount of use.)

Bultena, Gordon L.; Albrecht, Don; Womble, Peter. Freedom vs. control: a study of backpackers preferences for wilderness management. Leisure Sciences. 4: 297-310; 1981a. (Contains survey data on visitors to Denali National Park. Relevant subjects include attitudes toward rationing techniques, whether or not campfires should be allowed, selected closures, and other management techniques.)

Bultena, Gordon L.; Field, Donald R.; Womble, Peter; Albrecht, Don. Closing the gates: a study of backcountry use-limitation at Mount McKinley National Park. Leisure Sciences. 4: 249-267; 1981b. (Contains survey data on visitors to Denali National Park indicating that crowding is influenced by the number of encounters visitors expect.)

Bury, Richard L.; Fish, C. Ben. Controlling wilderness recreation: what managers think and do. Journal of Soil and Water Conservation. 35: 90-93; 1980. (Contains survey data on managers of wildernesses in three agencies. Describes the most common management techniques, reasons techniques were selected, and perceptions of effectiveness.)

Carothers, Steven W.; Johnson, Robert A.; Dolan, Robert. Recreational impacts on Colorado River beaches in Glen Canyon, Arizona. Environmental Management. 8: 353-358; 1984. (Compares the condition of Colorado River beaches in the Grand Canyon, where low-impact techniques and equipment are required, with beaches in Glen Canyon, where these are not required.)

Cole, David N. Managing ecological impacts at wilderness campsites: an evaluation of techniques. Journal of Forestry. 79: 86-89; 1981a. (Discusses the likely effectiveness of use dispersal among campsites, rest-rotation, and permanent closure of campsites, particularly those close to lakes.)

Cole, David N. Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness, Oregon: some management implications. Biological Conservation. 20: 247-270; 1981b. (Contains data on the condition of trails, campsites, and grazing areas. Differences in impact among vegetation types are described.)

Cole, David N. Vegetation of two drainages in Eagle Cap Wilderness, Wallowa Mountains, Oregon. Research Paper INT-288. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982a. 42 p. (Describes the management implications—such as trail and campsite suitability and special management problems—of 27 plant communities.)

Cole, David N. Wilderness campsite impacts: effect of amount of use. Research Paper INT-284. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982b. 34 p. (Contains data on the condition of campsites in the Eagle Cap Wilderness and how condition relates to amount of use and environmental conditions.)

Cole, David N. Controlling the spread of campsites at popular wilderness destinations. Journal of Soil and Water Conservation. 37: 291-295; 1982c. (Contains data on the number, distribution, and condition of campsites in a popular destination area in the Eagle Cap Wilderness. Means of minimizing impact in such situations are suggested.)

Cole, David N. Assessing and monitoring backcountry trail conditions. Research Paper INT-303. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983a. 10 p. (Describes means of monitoring trail condition. Contains data on trail condition in the Selway-Bitterroot Wilderness and how condition relates to amount of use, trail design, and location.)

Cole, David N. Campsite conditions in the Bob Marshall Wilderness, Montana. Research Paper INT-312. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station;

1983b. 18 p. (Contains data on campsite condition and how condition relates to type of use—backpacker, private horse, or outfitter—and environmental conditions.)

Cole, David N. Ecological changes on campsites in the Eagle Cap Wilderness, 1979 to 1984. Research Paper INT-368. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 15 p. (Contains data on 5 years' change in the condition of low-, moderate-, and high-use campsites.)

Cole, David N. Research on soil and vegetation in wilderness: a state-of-knowledge review. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: issues, state-of-knowledge, and future directions; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987: 135-177. (Reviews what is known about recreational impact on soil and vegetation, the factors that influence amount of impact, and approaches to mitigating problems.)

Cole, David N.; Benedict, Jim. Wilderness campsite selection—what should users be told? Park Science. 3(4): 5-7; 1983. (Proposes some principles for guiding visitors' selection of campsites. The appropriateness of campsites varies with amount of use in the area, resource durability, and the type of visitor.)

Cole, David N.; Dalle-Molle, John. Managing campfire impacts in the backcountry. General Technical Report INT-135. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 16 p. (Contains information on strategies for managing campfires, low-impact methods, and means of rehabilitating campfire scars.)

Cole, David N.; Fichtler, Richard K. Campsite impact in three western wilderness areas. Environmental Management. 7: 275-286; 1983. (Contains data on campsite condition from the Eagle Cap, Rattlesnake, and Mission Mountain Tribal Wildernesses and how condition relates to amount of use.)

Cole, David N.; Ranz, Beth. Temporary campsite closures in the Selway-Bitterroot Wilderness. Journal of Forestry. 81: 729-732; 1983. (Contains data on changes in the condition of both open and temporarily closed campsites around a mountain lake.)

Cole, David N.; Schreiner, Edward G. S. Impacts of backcountry recreation: site management and rehabilitation—an annotated bibliography. General Technical Report INT-121. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 58 p. (Contains annotations on sources of information about recreational impacts, their management, and how they can be rehabilitated.)

Dailey, Tom; Redman, Dave. Guidelines for roadless area campsite spacing to minimize impact of human-related noise. General Technical Report PNW-35. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1975. 20 p. (Summarizes information on noise, its perception by visitors, how environmental factors attenuate noise, and how campsites should be spaced to minimize noise impact.)

Dalle-Molle, John. Mt. Rainier backcountry plan: a case study. In: Ittner, R.; [and others], eds. Recreational impact on wildlands. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 234-239. (Describes the set of regulations implemented to deal with backcountry management problems at Mount Rainier National Park.)

DeBenedetti, Stephen H.; Parsons, David J. Protecting mountain meadows: a grazing management plan. Parks. 8(3): 11-13; 1983. (Describes a recreational stock research and management program—probably the most thorough program in wilderness—at Sequoia and Kings Canyon National Parks.)

Dustin, Daniel L.; McAvoy, Leo H. The limitation of the traffic light. Journal of Park and Recreation Administration. 2(3): 28-32; 1984. (Provides a discussion of the value and need for regulations in recreation management.)

Echelberger, Herbert E.; Moeller, George H. Use and users of the Cranberry Backcountry in West Virginia: insights for eastern backcountry management. Research Paper NE-363. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1977. 8 p. (Contains visitor survey data on attitudes about facilities, access manipulation, a user fee, use limitation, and allowing camping only on designated sites.)

Echelberger, Herbert E.; Leonard, Raymond E.; Adler, Steven P. Designated-dispersed tentsites. Journal of Forestry. 81: 90-91, 105; 1983. (Dispersed campsites—away from streams, trails, and other campsites—were designated in two backcountry areas in New Hampshire. Users of these sites were positive about them.)

Echelberger, Herbert E.; Leonard, Raymond E.; Hamblin, Marysewall Lindsey. The trail guide system as a backcountry management tool. Research Paper NE-266. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1978. 5 p. (Evaluates a guide booklet as a means of disseminating information to backcountry users. Evaluation took place in the White Mountains of New Hampshire.)

Fazio, James R. Communicating with the wilderness user. Bulletin 28. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1979. 65 p. (Describes sources of information used by visitors to the Selway-Bitterroot Wilderness. Evaluates the effectiveness of information at Rocky Mountain National Park. Offers recommendations for communicating with users.)

Fazio, James R.; Gilbert, Douglas L. Mandatory wilderness permits: some indications of success. Journal of Forestry. 72: 753-756; 1974. (Contains visitor survey data on the acceptability of the existing use control system in the backcountry of Rocky Mountain National Park.)

Fazio, James R.; Gilbert, Douglas L. Public relations and communications for natural resource managers. Dubuque, IA: Kendall/Hunt; 1981. 400 p. (A textbook with information useful in developing education and information programs.)

Fish, C. Ben; Bury, Richard L. Wilderness visitor management: diversity and agency policies. Journal of Forestry. 79: 608-611; 1981. (Contains survey data on managers of

wildernesses in the Forest Service, National Park Service, and Fish and Wildlife Service. Agency differences in management techniques and reasons for implementing controls are discussed.)

Gilbert, Gorman C.; Peterson, George L.; Lime, David W. Towards a model of travel behavior in the Boundary Waters Canoe Area. Environment and Behavior. 4: 131-157; 1972. (Contains an early list of alternative management techniques displayed along a continuum from direct to indirect.)

Godin, Victor B.; Leonard, Raymond E. Management problems in designated wilderness areas. Journal of Soil and Water Conservation. 34: 141-143; 1979. (Contains survey data on the frequency of different types of management problems as expressed by wilderness managers.)

Greist, David. Risk zoning: a recreation area management system and method of measuring carrying capacity. Journal of Forestry. 73: 711-714; 1975. (Proposes a use rationing system in which the risk of being denied access is inversely proportional to use intensity.)

Hammitt, William E. Alternatives to banning campfires. Parks. 7(3): 8-9; 1982. (Discusses an array of techniques for managing campfire impacts, from highly to minimally restrictive.)

Hardin, Garrett. The economics of wilderness. Natural History. 78(6): 20-27; 1969. (Contains an early discussion of some alternative techniques for rationing wilderness use.)

Helgath, Sheila F. Trail deterioration in the Selway-Bitterroot Wilderness. Research Note INT-193. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 15 p. (Contains data on how trail erosion varies with environmental conditions and amount of use.)

Hendee, John C.; Catton, William R., Jr.; Marlow, Larry D.; Brockman, C. Frank. Wilderness users in the Pacific Northwest—their characteristics, values, and management preferences. Research Paper PNW-61. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968. 92 p. (Contains survey data on visitors to the Glacier Peak, Three Sisters, and Eagle Cap Wildernesses. Relevant subjects include attitudes toward various types of facilities, controls on use and pack animals, and user fees.)

Hendee, John C.; Lucas, Robert C. Mandatory wilderness permits: a necessary management tool. Journal of Forestry. 71: 206-209; 1973. (Discusses the usefulness of mandatory permits as a management tool.)

Hendee, John C.; Lucas, Robert C. Police state wilderness: a comment on a comment. Journal of Forestry. 72: 100-101; 1974. (Discusses the value of permits, rebutting the arguments of Behan.)

Hendee, John C.; Stankey, George H.; Lucas, Robert C. Wilderness management. Miscellaneous Publication WO-1365. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 381 p. (A textbook on wilderness management. Relevant subjects include visitor attitudes toward wilderness conditions and management techniques, as well as some discussion of specific techniques.)

Hermann, Raymond; Williams, Owen R. Water resources research for wilderness: a state-of-knowledge review. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: issues, state-of-knowledge, and future directions; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987: 191-202. (A review of knowledge, including a discussion of water pollution problems in wilderness.)

Ittner, Ruth; [and others], eds. Recreational impact on wildlands. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979. 341 p. (A series of papers on wilderness impacts, including several on revegetation techniques in wilderness.)

Krumpe, Edwin E.; Brown, Perry J. Redistributing backcountry use through information related to recreation experiences. Journal of Forestry. 80: 360-364; 1982. (Describes and evaluates a "trail selector"—a brochure and map containing information on different trails—as a means of redistributing use.)

Leonard, R. E.; Spencer, E. L.; Plumley, H. J. Backcountry facilities: design and maintenance. Boston, MA: Appalachian Mountain Club; [n.d.]. 214 p. (Provides practical information on backcountry facilities—where they should be located and how they should be designed and maintained. Emphasizes the Eastern United States.)

Leonard, Raymond E.; Plumley, Harriet J. Human waste disposal in eastern backcountry. Journal of Forestry. 77: 349-352; 1979. (Summarizes information on the decomposition process, site requirements, visitor use capacity, esthetics, and cost of six alternative waste disposal methods.)

Lime, David W. Large groups in the Boundary Waters Canoe Area—their numbers, characteristics, and impact. Research Note NC-142. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1972. 4 p. (Contains a discussion of the probable impacts caused by large parties.)

Lime, David W.; Lucas, Robert C. Good informaton improves the wilderness experience. Naturalist. 28(4): 18-21; 1977. (Describes how information on use distribution, opportunities for fishing and wildlife observation, and safety factors was effective in redistributing use in the Boundary Waters Canoe Area.)

Lucas, Robert C. Use patterns and visitor characteristics, attitudes and preferences in nine wilderness and other roadless areas. Research Paper INT-253. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 89 p. (Contains survey data on visitors to seven wildernesses and one roadless area in Montana and the Desolation Wilderness in California. Relevant subjects include attitudes toward encounters, various types of facilities, rationing techniques, and other management techniques.)

Lucas, Robert C. Redistributing wilderness use through information supplied to visitors. Research Paper INT-277. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 15 p. (Evaluates the effectiveness of a

brochure in redistributing use in a portion of the Selway-Bitterroot Wilderness. Offers suggestions on how to increase effectiveness.)

Lucas, Robert C. Recreation regulations—when are they needed? Journal of Forestry. 80: 148-151; 1982. (Contains a seven-step procedure for evaluating potential management actions.)

Lucas, Robert C. Visitor characteristics, attitudes, and use patterns in the Bob Marshall Wilderness complex, 1970-82. Research Paper INT-345. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 32 p. (Contains survey data on visitors to the Bob Marshall, Great Bear, and Scapegoat Wildernesses, taken in both 1970 and 1982. Relevant subjects include attitudes toward encounters, various types of facilities, rationing techniques, and other management techniques.)

Manning, Robert E. Strategies for managing recreational use of National Parks. Parks. 4(1): 13-15; 1979. (Discusses a classification of recreation management techniques as they relate to a strategic purpose.)

Manning, Robert E. Studies in outdoor recreation. Corvallis, OR: Oregon State University Press; 1985. 166 p. (Reviews and synthesizes the social science literature in outdoor recreation.)

Manning, Robert E.; Powers, Lawrence A. Peak and off-peak use: redistributing the outdoor recreation/tourism load. Journal of Travel Research. 23(2): 25-31; 1984. (Discusses the potential to shift use from peak to off-peak periods. Data from a survey of Vermont State park campers suggest how and where such a program might be effective.)

Manning, Robert E.; Callinan, Elaine A.; Echelberger, Herbert E.; [and others]. Differential fees: raising revenue, distributing demand. Journal of Park and Recreation Administration. 2(1): 20-38; 1984. (Differential fees—higher fees for more popular campsites—in three Vermont State parks resulted in more even distribution of campsite use and a small increase in revenues.)

Marion, Jeffrey L.; Cole, David N.; Bratton, Susan P. Exotic vegetation in wilderness areas. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 114-120. (Discusses problems with exotic plants and how they might be managed.)

Marion, Jeffrey L.; Merriam, L. C. Recreational impacts on well-established campsites in the Boundary Waters Canoe Area Wilderness. Station Bulletin AD-SB-2502. St. Paul, MN: University of Minnesota, Agricultural Experiment Station; 1985. 16 p. (Contains data on the condition of campsites and how condition relates to amount of use and age of the site.)

Marion, Jeffrey L.; Sober, Toivo. Wilderness campsite management in the Boundary Waters Canoe Area Wilderness. Northern Journal of Applied Forestry. [In press]. (Describes the intensive campsite management program that has been implemented in the most heavily used wilderness in the country.)

Martin, Burnham H.; Taylor, Dorothy T. Informing backcountry visitors: a catalog of techniques. Boston, MA: Appalachian Mountain Club; 1981. (Summarizes the pros and cons of techniques for disseminating information to users. Evaluates effectiveness, popularity, necessary training, cost, advantages, and disadvantages.)

McCool, Stephen F.; Utter, Jack. Preferences for allocating river recreation use. Water Resources Bulletin. 17: 431-437; 1981. (Contains survey data on river runners on the Middle Fork of the Salmon River. Acceptability of rationing techniques is examined.)

McEwen, D.; Tocher, S. R. Zone management: key to controlling recreational impact in developed campsites. Journal of Forestry. 74: 90-93; 1976. (Stresses the importance of concentrating and channeling use on and around campsites. Useful in thinking about the design and maintenance of heavily used sites and areas.)

Murray, Judith Buckley. Appalachian Trail users in the southern National Forests: their characteristics, attitudes and management preferences. Research Paper SE-116. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1974. 19 p. (Contains visitor survey data on attitudes about facilities.)

Muth, Robert M.; Clark, Roger N. Public participation in wilderness and backcountry litter control: a review of research and management experience. General Technical Report PNW-75. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978. 12 p. (Describes how to motivate visitors to help clean up and remove litter.)

Parsons, David J. The recovery of Bullfrog Lake. Fremontia. 7(2): 9-13; 1979. (Describes how much recovery has occurred on campsites that have been closed for about 15 years in Kings Canyon National Park.)

Parsons, David J. Wilderness protection: an example from the southern Sierra Nevada, USA. Environmental Conservation. 10: 23-30; 1983. (Describes and assesses the effectiveness of a series of regulations imposed to manage a heavily used portion of Kings Canyon National Park.)

Parsons, David J. On the use of campsite impact data as a basis for determining wilderness use capacities. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 449-455. (Describes how campsite impact data—at Sequoia and Kings Canyon National Parks—were used to set trailhead quotas on use.)

Parsons, David J.; Stohlgren, Thomas J.; Fodor, Paul A. Establishing backcountry use quotas: an example from Mineral King, California. Environmental Management. 5: 335-340; 1981. (Describes how trailhead quotas on use of a portion of Sequoia National Park were derived.)

Peterson, George L. The computer takes a canoe trip. Naturalist. 28(4): 9-11; 1977. (Describes a simple, computer-facilitated method of setting trailhead quotas to avoid congestion of internal locations.)

Peterson, George L.; Lime, David W. People and their behavior: a challenge for recreation management. Journal of Forestry. 77: 343-346; 1979. (Describes a framework for analyzing recreation management problems and searching for potential solutions to problems.)

Plager, Anna; Womble, Peter. Compliance with backcountry permits in Mt. McKinley National Park. Journal of Forestry. 79: 155-156; 1981. (Evaluates visitor compliance with a use limitation program at Denali National Park. Describes reasons for noncompliance and user opinions of the program.)

Potter, Fletcher I., III; Manning, Robert E. Application of the wilderness travel simulation model to the Appalachian Trail in Vermont. Environmental Management. 8: 543-550; 1984. (Describes how the wilderness travel simulation model can be used as a recreation management tool, particularly as part of a use limitation program.)

Proudman, Robert D. AMC field guide to trail building and maintenance. Boston, MA: Appalachian Mountain Club; 1977. 193 p. (A practical handbook on how to locate, construct, and maintain trails.)

Ream, Catherine H. Human-wildlife conflicts in backcountry: possible solutions. In: Ittner, R.; [and others], eds. Recreational impact on wildlands. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1979: 153-163. (Discusses problems of wildlife impact and possible management solutions.)

Ream, Catherine H. Impacts of backcountry recreationists on wildlife: an annotated bibliography. General Technical Report INT-81. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 62 p. (Discusses problems of wildlife impact, potential solutions, and sources of information.)

Roggenbuck, Joseph W.; Berrier, Deborah L. Communications to disperse wilderness campers. Journal of Forestry. 79: 295-297; 1981. (Evaluates the effectiveness of brochures and personal contact in moving campers away from a congested camping area in the Shining Rock Wilderness.)

Roggenbuck, Joseph W.; Watson, Allan E.; Stankey, George H. Wilderness management in the southern Appalachians. Southern Journal of Applied Forestry. 6: 147-152; 1982. (Contains survey data on visitors to the Linville Gorge, Shining Rock, and Joyce Kilmer/Slickrock Wildernesses. Relevant subjects include attitudes toward management problems, encounters, use controls, specific rationing techniques, and other management techniques.)

Rowell, Allen L. A wilderness travel simulation model with graphic presentation of trail data. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 478-482. (Describes a "user-friendly" simulation model that can be useful in developing a use limitation program.)

Shechter, Mordechai; Lucas, Robert C. Simulation of recreational use for park and wilderness management. Baltimore, MD: Johns Hopkins Press; 1978. 220 p. (Discusses the use of simulation in developing wilderness management programs. Describes and applies simulation models to several settings.)

Shelby, Bo; Danley, Mark S.; Gibbs, Kenneth C.; Petersen, Margaret E. Preferences of backpackers and river runners for allocation techniques. Journal of Forestry. 80: 416-419; 1982. (Contains survey data on river runners in Hells Canyon Wilderness and backpackers in the Mount Jefferson and Eagle Cap Wildernesses. Relevant subjects include attitudes toward rationing techniques.)

Shelby, Bo; Heberlein, Thomas A.; Vaske, Jerry J.; Alfano, Geraldine. Expectations, preferences, and feeling crowded in recreation activities. Leisure Sciences. 6: 1-14; 1983. (Contains survey data from six settings, including data on rafters on the Rogue River and in Grand Canyon. Illustrates how expectations related to encounter levels influence perceptions of crowding.)

Silverman, G.; Erman, D. C. Alpine lakes in Kings Canyon National Park, California: baseline conditions and possible effects of visitor use. Journal of Environmental Management. 8: 73-87; 1979. (Contains data on the water quality of some heavily used lakes, including data on the incidence of fecal contamination.)

Stankey, George H. Visitor perception of wilderness recreation carrying capacity. Research Paper INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 61 p. (Contains survey data on visitors to the Bob Marshall, High Uinta, and Boundary Waters Canoe Area Wildernesses. Relevant subjects include attitudes toward encounters, conflicting uses, various types of facilities, rationing techniques, and other management techniques.)

Stankey, George H. Use rationing in two southern California wildernesses. Journal of Forestry. 77: 347-349; 1979. (Contains visitor survey data on the acceptability of existing use limitations at San Gorgonio and San Jacinto Wildernesses.)

Stankey, George H. A comparison of carrying capacity perceptions among visitors to two wildernesses. Research Paper INT-242. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 34 p. (Contains survey data on visitors to the Desolation and Lee Metcalf Wildernesses. Relevant subjects include attitudes toward encounters, use controls, rationing techniques, allowing access to deteriorate, assigning visitors to campsites, and party size limits.)

Stankey, George H.; Baden, John. Rationing wilderness use: methods, problems, and guidelines. Research Paper INT-192. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 20 p. (Describes the pros and cons of alternative techniques for rationing wilderness use.)

Stankey, George H.; Schreyer, Richard. Wilderness visitor attitudes and behavior: a state-of-knowledge review. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: issues, state-of-knowledge, and future directions; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987: 246-293. (Relevant subjects include reviews of visitor attitudes toward management problems and wilderness conditions, such as encounters, as well as attitudes toward facilities, rationing techniques, and other management techniques.)

Stankey, George H.; Cole, David N.; Lucas, Robert C.; [and others]. The limits of acceptable change (LAC) system for wilderness planning. General Technical Report INT-176. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 37 p. (Proposes a framework for identifying management problems, developing a response to problems, and monitoring effectiveness.)

Starkey, Edward E.; Larson, Gary. Research on fish and wildlife: a state-of-knowledge review. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: issues, state-of-knowledge, and future directions; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1987: 178-190. (Reviews research on recreational impacts on wildlife and fish.)

Taylor, T. P.; Erman, D. C. The response of benthic plants to past levels of human use in high mountain lakes in Kings Canyon National Park, California, U.S.A. Journal of Environmental Management. 9: 271-278; 1979. (Contains data on nutrient content and plant growth in lakes and how these conditions relate to use levels around these lakes. One of the few case studies documenting substantial recreational impact on water quality in wilderness.)

Temple, Kenneth L.; Camper, Anne K.; Lucas, Robert C. Potential health hazard from human wastes in wilderness. Journal of Soil and Water Conservation. 37: 357-359; 1982. (Presents data indicating that shallow burial of feces—in cat-holes—does not result in quick destruction of intestinal pathogens.)

Thornburgh, Dale A. Responses of vegetation to different wilderness management systems. In: Lucas, Robert C., compiler. Proceedings—national wilderness research conference: current research; 1985 July 23-26; Fort Collins, CO. General Technical Report INT-212. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986: 108-113. (Evaluates the effectiveness of various techniques implemented over the years in an attempt to manage impact around a popular lake in Glacier Peak Wilderness.)

U.S. Department of Agriculture, Forest Service. Techniques and equipment for wilderness horse travel. 2300-Recreation, 8123 2403. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center; 1981. 42 p. (Describes equipment and techniques that horse parties can use to minimize their impact.)

van Wagtendonk, Jan. The effect of use limits on backcountry visitation trends in Yosemite National Park. Leisure Sciences. 4: 311-323; 1981. (Describes how a use limitation system has shifted spatial and temporal use distributions.)

Wagar, J. V. K. Certified outdoorsmen. American Forests. 46: 490-492, 524-525; 1940. (An early proposal that minimum skills be required.)

Wagar, J. Alan. The carrying capacity of wildlands for recreation. Forest Science Monograph 7. Washington, DC: Society of American Foresters; 1964. 23 p. (Contains an early discussion of strategies and techniques that can be used to deal with wildland recreational problems.)

Washburne, Randel F.; Cole, David N. Problems and practices in wilderness management: a survey of managers. Research Paper INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 56 p. (Contains survey data on managers of wilderness. Describes the frequency of management problems and techniques implemented to deal with these problems. An appendix lists implemented techniques for all wildernesses and 61 proposed wildernesses in 1980.)

Weaver, T.; Dale, D. Trampling effects of hikers, motorcycles and horses in meadows and forests. Journal of Applied Ecology. 15: 451-457; 1978. (Contains data comparing the impacts caused by hikers and horses.)

West, Patrick C. Effects of user behavior on the perception of crowding in backcountry forest recreation. Forest Science. 28: 95-105; 1982. (Contains survey data on backcountry visitors to the Sylvania Recreation Area, MI, illustrating how conflicts with other types of users affect perceived crowding. Advocates "behavioral zoning.")

Cole, David N.; Petersen, Margaret E.; Lucas, Robert C. 1987. Managing wilderness recreation use. Gen. Tech. Rep. INT-230. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 60 p.

Describes pros and cons of potential solutions to common wilderness recreation problems. Covers the purpose of each potential solution, costs to visitors and management, effectiveness, other considerations, and sources of additional information.

KEYWORDS: wilderness, recreation, management techniques, management strategies, backcountry, wilderness planning

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

General Technical
Report INT-231

Guidelines for Prescribed Burning Sagebrush-Grass Rangelands in the Northern Great Basin

**Stephen C. Bunting
Bruce M. Kilgore
Charles L. Bushey**

RESEARCH SUMMARY

This report is primarily designed for those with limited fire experience who want to begin a program of prescribed fire in sagebrush-grass vegetation. The guidelines outline procedures and considerations for planning and conducting prescribed fires in such vegetation. Fire effects information is summarized by the major series of sagebrush species as described in recent habitat type classifications for the northern Great Basin, Snake River Plains, and Columbia River Basin. An annotated bibliography of literature published since 1980 on fire-sagebrush-grass vegetation is appended. The report recommends monitoring techniques to be used for evaluating effects of prescribed fire, a step that is becoming increasingly important in land management. Procedures for evaluating effects on plant cover, plant density, species composition, plant mortality, and biomass production are included.

ACKNOWLEDGMENTS

The authors would like to thank the many people who reviewed the quidelines for prescribed burning and have contributed suggestions. These include Jean Findley, Phil Range, Joe Carter, Loren Anderson, Al Steuter, Min Hironaka, Al Winward, George Gruell, Gardner Ferry, Terry Rich, Irwin Cowley, Stan Coloff, Jim Brown, William Fischer, Melanie Miller, and many others in the Bureau of Land Management and USDA Forest Service. Research was supported by the U.S. Department of the Interior, Bureau of Land Management, Washington Office Divisions of Rangeland Resources and Fire and Aviation Management; Intermountain Research Station, USDA Forest Service; and the Forest, Wildlife and Range Experiment Station, University of Idaho, Contribution No. 289.

CONTENTS

THE AUTHORS

STEPHEN C. BUNTING is an associate professor of Range Resources in the College of Forestry, Wildlife and Range Sciences, University of Idaho. He received his B.S. degree in range and forest management from Colorado State University in 1971. He received his M.S. and Ph.D. degrees in range science from Texas Tech University in 1974 and 1978, respectively. In 1978 he joined the faculty at the University of Idaho. He is currently conducting research on fire effects in sagebrush-grass, pinyon-juniper, and ponderosa pine vegetation.

BRUCE M. KILGORE received his bachelor's degree from the University of California, Berkeley, in 1952 in wildlife conservation, his master's degree from the University of Oklahoma in 1954 in journalism, and his Ph.D. from the University of California, Berkeley in 1968 in zoology. From 1964 to 1968, he did research on the response of populations of breeding birds to prescribed burning in giant sequoia-mixed conifer forests. In 1968, he joined the National Park Service at Sequoia-Kings Canyon National Parks where he conducted research on the fire ecology of sequoia-mixed conifer and red fir forests of the Sierra Nevada in California. In 1972, he transferred to the Western Regional Office of the National Park Service in San Francisco as Associate Regional Director for Resources Management and Planning. In 1981, he joined the U.S. Department of Agriculture, Forest Service, at the Northern Forest Fire Laboratory, Missoula, MT, where he conducted research on use of prescribed fire in both natural areas such as Glacier National Park as well as use of prescribed fire in sagebrush-grass and pine-fir-larch types. He served as leader of the Fire Management in Natural Ecosystems research work unit. In 1985, he accepted his current assignment as Regional Chief Scientist and Chief of the National Park Service's Western Region Division of Natural Resources and Research in San Francisco.

CHARLES L. BUSHEY received his B.A degree in biology from Monmouth College in 1973 and his M.S. degree in botany from Southern Illinois University-Carbondale in 1985. He is currently a research plant ecologist with Systems for Environmental Management and a prescribed fire specialist/fire ecologist with Montana Prescribed Fire Services, Inc., Missoula, MT. He has been the principal investigator for numerous cooperative studies on forest and sagebrush/grassland fuels, fire behavior, and vegetation response to fire. He was previously employed by the Fire Effects and Use Research and Development Program at the Northern Forest Fire Laboratory, Missoula, MT; NALCO Environmental Sciences, Northbrook, IL; and the Lake County Forest Preserve District, Libertyville, IL.

August 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

Guidelines for Prescribed Burning Sagebrush-Grass Rangelands in the Northern Great Basin

Stephen C. Bunting
Bruce M. Kilgore
Charles L. Bushey

INTRODUCTION

Use of prescribed burning for managing sagebrush-grass ranges has increased dramatically in recent years. Consequently, many land managers are interested in starting or expanding prescribed burning programs. Often these people have had only limited fire experience. These guidelines are not a substitute for experience. But they will result in better planning and scheduling of fires and increase the probability of achieving objectives.

The guidelines outline some procedures and considerations required when planning and conducting prescribed fires in sagebrush-grass ranges and monitoring the effects of these fires. The literature on sagebrush-grass fire effects is summarized briefly and a comprehensive bibliography of sagebrush-grass fire literature published since 1980 is included in appendix B.

The sagebrush-grass range region is extensive and includes portions of all 11 Western States. The climatic patterns and vegetation composition vary considerably throughout this vast region. In the southern portion, sagebrush-grass vegetation is influenced by the desert grassland and hot desert shrub vegetation. Consequently, sagebrush communities may contain substantial amounts of warm season grasses. In the eastern portion, sagebrush-grass ranges gradually merge with vegetation characteristics of the short grass plains and mixed grass prairie. The vegetation and climate of these sagebrush areas will vary considerably when compared to the cool season sagebrush-grass ranges of the northern Great Basin and Columbia River Basin.

These guidelines are based, in large part, on the authors' experience in applying prescribed fire to sagebrush-grass ranges in the northern Great Basin and Columbia River drainage. Because of variation in both environmental conditions and plant community composition, these guidelines should not be indiscriminantly applied to sagebrush-grass communities in the southern Great Basin and east of the Continental Divide. Many principles and considerations required to conduct prescribed fires, however, apply throughout the sagebrush-grass region.

FIRE EFFECTS

Recent reviews of fire's effect on the major plant species that comprise sagebrush-grass communities include those of Wright and others (1979), Lotan and others (1981), and Wright and Bailey (1982). In addition to fire's effect, a general review of sagebrush ecological literature was recently written by Tisdale and Hironaka (1981) and has been summarized in a symposium proceedings compiled by McArthur and Welch (1986). Blaisdell and others (1982) provide a summary of the most important literature that may be helpful in managing sagebrush-grass ranges, including the use of prescribed fire. Harniss and others (1981) have published a computerized bibliography of selected sagebrush species. This paper will not include a review of fire on particular species but will include a list of the major references that include information on these species published since 1980 (appendix B).

Most current literature does not integrate the importance of vegetation classification systems with fire effects on the various species involved. Blaisdell and others (1982) do stress the importance of habitat types to land management treatments. This review will utilize the habitat type concept of vegetation classification as described by Daubenmire (1952). Daubenmire's approach has many distinct advantages over other classification systems (Hironaka and others 1983). Classifications have been developed for portions of the northern half of the sagebrush region (Hironaka and others 1983; Mueggler and Stewart 1980; Schlatterer 1972; Zamora and Tueller 1973) and classifications for other areas are being developed. It has long been realized that sagebrush-grass vegetation is complex and the response to fire and other factors varies considerably between geographic areas and subspecies. A knowledge of plant species response after fire, combined with an appreciation of the importance of habitat type, gives one a greater ability to predict fire response. Better results are obtained when fire is used on areas receiving more precipitation than the mean for that taxonomic unit. The habitat type also can be utilized as a framework to develop a data storage-retrieval system in

which to catalog new information (Hironaka and others 1983). This section includes a discussion of two other factors that may greatly affect fire response—ecological status (range condition) and season of the fire.

Habitat Type

Early vegetation maps used by the land management agencies classified all sagebrush-grass vegetation into a single classification unit. Later work separated sagebrush vegetation into tall and low sagebrush types. In recent years the classifications have become more refined. Much of the refinement was made possible by advances in the taxonomy of the sagebrushes themselves (Beetle 1960; Beetle and Young 1965; Winward and Tisdale 1977). Vegetation classification systems are becoming increasingly sophisticated as land management becomes more intensive. This enables researchers to explain observed differences in vegetation response to fire and other disturbances on the basis of habitat type.

More recently, attempts have been made to develop a system of classification for seral communities within a habitat type (Hann 1982; Schott 1981). This seral classification will be an important sequel to the habitat type classification (Hironaka and others 1983). It is of particular interest for those planning prescribed fires because most communities are disturbed to some degree and many are seral to climax conifer or other vegetation. Prescribed fire is frequently used as a tool to maintain seral communities, which are more desirable for some land management objectives.

The ecological relationships of the northern portion of the sagebrush-grass region have been reviewed (Hironaka 1979; Hironaka and others 1983; Johnson 1979; Tisdale and Hironaka 1981; West 1979). The following discussion will consider the ecological role of fire in these communities. The habitat types will be grouped by the dominant sagebrush present (Series Level). Discussions at the habitat type level would be more precise, but information is not available on fires at this level. However, significant variations that are known will be included (table 1).

Mountain Big Sagebrush Series—This subspecies occurs on the most mesic and usually highest elevations of the three subspecies of big sagebrush. As a result this

Table 1—Environmental characteristics and general fire response of sagebrush grasslands grouped at series level of classification

Series	Precipitation	Environmental characteristics and fire response
	Inches	
Mountain big sagebrush	12-20	Very productive sites; seeds of sagebrush establish readily; sage may return to preburn condition within 15 to 25 years; community contains high diversity of perennial forbs; herbaceous productivity usually enhanced by burning.
Species "X" (form of mountain big sagebrush)	>12	Annual grasses frequently important component of community; frequently burned by wildfires at current time; shrubs may be removed from community by repeated wildfires.
Basin big sagebrush	10-18	Most extensive areas now cultivated due to deep soils; many sites depleted of perennial grasses and invaded with cheatgrass; favorable response to fire occurs if adequate understory is present.
Wyoming big sagebrush	7-12	Most arid series; slow sagebrush reinvasion after fire; perennial depleted in many warmer habitat types and replaced with cheatgrass; few perennial forbs present in any range condition; invasion by rabbitbrush may be problem following fire; difficult to burn due to low sagebrush cover and low fine fuel loading.
Threetip sagebrush	11-16	Resprouts but varies considerably regionally; horsebrush and rabbitbrush often present and become a problem following fire.
Silver sagebrush		Minor importance in Great Basin but extensive east of Continental Divide; sprouter, particularly on spring burns; located on fertile, well-drained sites capable of producing over 2,000 lb/acre herbaceous material.
Dwarf sagebrushes	variable	Low fine fuel loadings make burning difficult; can sometimes be used as fire breaks; many sagebrush species in this group are preferred forage species.

series is one of the most productive of the sagebrush types (fig. 1). It is not known to resprout following fire. Mountain big sagebrush, however, is well adapted to becoming established following fire. The seeds germinate more readily following a light heat treatment than if untreated (Chaplin and Winward 1982). The plants also grow rapidly and may reach reproductive maturity within 3 to 5 years. The combination of these two factors favors the rapid reestablishment of a new stand of sagebrush. Sagebrush may return to preburn density and cover within 15 to 20 years following the fire. Establishment after severe fires may proceed more slowly, and sagebrush may not dominate the area for 30 years (Blaisdell and others 1982).

Bitterbrush is often found in communities within the mountain big sagebrush series. It is normally a decumbent form and is moderately adapted to spring and fall fires in this series. Survival averaged 45 percent for bitterbrush within mountain big sagebrush communities in the Northern Rocky Mountains (Bunting and others 1984). Most of the other shrub species found within this series also resprout (Hironaka and others 1983).

(A)

(B)

Figure 1—Representative areas of the *Artemisia tridentata tridentata/Festuca idahoensis* h.t. in central Idaho. (A) A stand that has not been burned for at least 50 years. (B) An area that was prescribed-burned in the fall 4 years earlier.

If rabbitbrush occupies a site, it usually resprouts following fires. It does not, however, seem to increase in density in most instances as has been observed in other sagebrush communities. Horsebrush in this series follows the same pattern as rabbitbrush.

The herbaceous component of the mountain big sagebrush series is among the most productive of all the sagebrush communities. Many communities within this series are also rich in species number of both grasses and forbs. Kuntz (1982) found that the herbaceous component changed little following spring prescribed burns. Vegetation was dominated by perennial forbs for the first 2 to 3 years. After that the grasses dominated and probably will continue to do so until sagebrush reestablishes. Minor changes in density were observed for grasses and forbs following spring fires. The greatest changes were increases in the productivity of the individual plants occupying the site at the time of the fire (Kuntz 1982).

"Species X" is a form of mountain big sagebrush (Winward and Tisdale 1977) found primarily in western Idaho and eastern Oregon. It is restricted to a narrow zone where the annual precipitation exceeds 12 inches, the elevation is less than 4,500 feet, and the summers are relatively warm (Hironaka and others 1983). It is easily confused with basin big sagebrush because of similarities in growth form and stature of the shrubs.

The response of the "species X" communities to fire is more similar to basin big sagebrush than the other mountain big sagebrush communities. Bitterbrush, when found in "species X" communities, is of the columnar form and is severely reduced by fire (Bunting and others 1984). The perennial grasses such as Idaho fescue and bluebunch wheatgrass seem to be more sensitive to fire, and the community frequently has a larger component of annual grasses present. This probably reflects the warmer and drier climate this type has as compared to the other mountain big sagebrush communities.

Many of the "species X" communities are on relatively steep slopes. Combined with the dominance of cheatgrass and medusahead in the understory and the potential for human and lightning-caused fires, this steepness has resulted in much of the original area being repeatedly burned. These frequently burned areas are dominated by annual grasses. Sagebrush and bitterbrush have been significantly reduced. Most burned areas have not shown great increases in rabbitbrush, although it is often present.

Basin Big Sagebrush Series—The majority of the historic area of this series is currently under intensive agricultural cultivation and is now restricted primarily to field edges, swales, and along water drainage ways in areas dominated by other sagebrush species. It does not resprout (Blaisdell 1953), and repeated fires have eliminated it from many of the remaining sites (Pickford 1932).

The basin big sagebrush series is usually found on productive sites, and the sagebrush canopy coverage may exceed 60 percent (Neuenschwander 1980). The fuels are normally adequate to carry a fire. Two common problems have been observed with this series in relation to prescribed burning. The part of this series still remaining occurs topographically in areas preferred by livestock. Herbaceous utilization by livestock is often greater than the surrounding vegetation types. Fire will intensify the use in these areas, particularly if adequate areas of surrounding vegetation are not also burned. After the fire, the loss of sagebrush protection may result in a decrease in density of these grasses even though perennial grasses are increasing in productivity and density on upland areas.

A second problem may exist in communities in the warmer dry portions of the basin big sagebrush series. The understory of these areas is frequently dominated by cheatgrass. The cheatgrass will increase following a fire (Countryman and Cornelius 1957) making establishment of perennial grasses difficult.

When adequate stands of perennial grasses such as bluebunch wheatgrass or Great Basin wildrye occur on the site, favorable increases in productivity often result unless the fire is extremely severe. In addition to increased productivity, substantial increases in herbaceous forage availability may result due to the decreases in density and canopy coverage of sagebrush following fire in the older stands (fig. 2).

Wyoming Big Sagebrush Series—This series occurs on the most arid areas within the range of big sagebrush. Annual precipitation may average less than 7 inches in some habitat types (Hironaka and others 1983). The low productivity and resultant lack of fine fuels of these areas often make prescribed burning difficult. The coverage of Wyoming big sagebrush seldom exceeds 25 percent, and this may contribute to the difficulty in getting a fire to carry through many communities of this series.

Cheatgrass predominates in lower successional stands of the Wyoming big sagebrush series in western Idaho, northern Nevada, and Oregon. An abundance of cheatgrass increases the likelihood of fire in these areas and many have been burned repeatedly by wildfires. This has resulted in a conversion to nearly pure stands of cheatgrass (fig. 3). While burning in this series will remove brush, it will not provide more perennial grass where cheatgrass has become dominant. The annual grass stage is relatively stable with bottlebrush squirreltail being the primary perennial grass to increase on the more arid sites. Once an area burns and becomes dominated by cheatgrass, the risk of wildfire becomes much greater (Hironaka and others 1983) and the likelihood of conversion back to perennial grasses by natural regeneration is greatly diminished. Cheatgrass rarely is present in large amounts in Wyoming big sagebrush communities in eastern Idaho.

Wyoming big sagebrush will establish readily from seed if seed is available. Slow growth, however, reduces the rate at which it recovers as compared to the other big sagebrush subspecies. Repeated fires will eliminate the onsite seed source and reinvasion into these areas will be extremely slow.

Rabbitbrush may become a problem on areas that are repeatedly burned, but this varies considerably within Wyoming big sagebrush series. Rabbitbrush resprouts readily throughout this series, but establishment from seed is not as common in eastern Idaho and Wyoming as it is farther west. Repeated fires in western Idaho have resulted in very dense stands of rabbitbrush (fig. 4).

Species diversity is much lower in the Wyoming big sagebrush series as compared to the mountain sagebrush

(A)

(B)

Figure 2—(A) Basin big sagebrush with an understory of Great Basin wildrye. Many of the mature sagebrush plants were older than 40 years. (B) A similar community prescribed-burned during the fall 4 years earlier. The wildrye has remained vigorous and productive.

Figure 3—Annual grass community dominated by cheatgrass on the lower Snake River Plains. Sites with seral stages of big sagebrush that are burned by either prescribed or wildfires often become dominated with annual grasses. Great Basin wildrye (foreground) has survived this high-severity wildfire.

Figure 4—Rubber rabbitbrush may become dominant on sites that are burned repeatedly, such as this site on the lower Snake River Plains. It resprouts readily and becomes established from seed after disturbance. Resprouting and seedling establishment varies greatly, however, over the wide range of the species.

series. This is particularly true for perennial forbs. Normally these communities do not have many perennial forbs present in the unburned condition, and this component does not increase as a result of fire. Consequently, the potential for increasing perennial forb production with fire is much less than with many other sagebrush types (fig. 5).

(A)

(B)

Figure 5—Representative sites of areas classified as *Artemisia tridentata wyomingensis/Agropyron spicatum* h.t. (A) A site that has not been disturbed for over 50 years. (B) A site that was prescribed-burned in the fall 3 years previously. This community is dominated by bluebunch wheatgrass; few perennial forbs increase as a result of the fire.

The perennial grasses found in this series are in general more sensitive to fire than the same species associated with the more mesic subspecies of big sagebrush. Bluebunch wheatgrass and Great Basin wildrye are the most adapted to fire of the perennial grass species naturally occurring in this series and generally recover quickly to preburn biomass productivity levels. Thurber's needlegrass is one of the grass species least adapted to fire and is usually severely reduced following fire (Wright and others 1979). Sandberg bluegrass may suffer high initial mortality due to the fire but seems to reproduce readily from seed in following years.

Threetip Sagebrush—This series of sagebrush communities is restricted in area and located primarily in eastern Idaho, eastern Oregon, Wyoming (Beetle 1960), and southwestern Montana (Morris and others 1976). Climatically threetip sagebrush occupies a position between the Wyoming and the mountain big sagebrush series (Hironaka and others 1983). In most respects the herbaceous component is also intermediate in its response to fire. There are, however, some factors that are different enough to warrant noting.

Threetip sagebrush has been reported to be a prolific resprouter (Beetle 1960; Morris and others 1976; Pechanec and others 1965). This ability varies, which is evidence that several ecotypes exist (Hironaka and others 1983). In our experience, those populations in eastern Idaho seem to have the greatest resprouting potential. Populations in the central portion of Idaho's Snake River Plains (area west of the Craters of the Moon National Monument) have low resprouting ability. Populations in eastern Oregon have moderate resprouting potential. The southwestern Montana populations resprout readily.

Threetip sagebrush communities often include rabbitbrush and horsebrush. Both associated shrubs resprout and establish from seed readily following fire. The presence of rabbitbrush and horsebrush indicates that fire has played an important role in this series (Hironaka and others 1983). Resprouting and seedling establishment of these species certainly needs to be considered when planning prescribed fires in these communities.

Cheatgrass is present in many areas of threetip sagebrush series. But it seldom becomes a problem following fire or other types of disturbance (Hironaka and others 1983).

Silver Sagebrush Series—Little information is available on the response of this series. Silver sagebrush is of minor importance in the Great Basin but is more extensive east of the Continental Divide (Beetle 1960) and may dominate areas of eastern Montana (Morris and others 1976). Silver sagebrush was noted to be a sprouter (McArthur and others 1979) but apparently can be controlled by fire in some areas of its range (Wright and Bailey 1980). Blaisdell and others (1982) referred to silver sagebrush as an occasional respouter following fire. White and Currie (1982) found that on the Great Plains it resprouted vigorously on spring burns, but that fall burns resulted in greater mortality and low vigor of resprouts. Spring burns, however, increased production of western wheatgrass and bluegrasses more than fall burns.

Dwarf Sagebrushes—This group includes black sagebrush, stiff sagebrush, low sagebrush, and others. These species normally occur on shallower and less productive sites than the taller sagebrush species. Due to low productivity, these sites are difficult to burn and can frequently be used as natural firebreaks. Dwarf sagebrush habitat types seldom have fuel loadings capable of carrying a fire (Blaisdell and others 1982). Care must be taken, however, in above average production years because they may be capable of carrying a fire at this time. All species are easily killed by fire. Mortality of bunchgrasses seems to be low on burned areas we have observed, but the low site potential limits the increase in herbaceous production. Dwarf sagebrush species are often preferred forage plants for livestock and wildlife (Beardall and Sylvester 1976). Consequently, prescribed burning cannot be recommended widely in these communities.

Ecological Status

One of the most important factors involved in determining the response of an area to fire is the preburn plant composition. Numerous studies have indicated that the initial stages of secondary succession following fire are dominated by plants that were present prior to the burn and which survived the fire (Armour and others 1984; Connell and Slatyer 1977; Kuntz 1982; Lyon and Stickney 1976). The surviving vegetation influences postfire succession in two ways. First, surviving plants occupy space in the community, preventing the establishment of others. Second, they produce the seed which influences the availability of propagules that will establish on the unoccupied sites (Cattelino and others 1979; Horn 1975a, 1975b).

Sites considered for range improvement are usually those that have high potential but are currently producing considerably below that potential. These sites will have the greatest potential for improvement (Vallentine 1971). But this is usually not the best criteria for selecting sites to prescribe burn if increased perennial grass production is an objective. As previously discussed, these sites may be difficult to burn because of the lack of fine fuels (fig. 6). If burned, the areas may have few if any desirable perennial forage species present, and consequently the recovery may be slow unless seeds are supplied artificially. It has been observed that herbaceous productivity following herbicide treatment is unsatisfactory when perennial grass density is less than one plant per 10 ft^2 in sagebrush-grass vegetation (Hyder and Sneva 1956). Similar densities are probably necessary for adequate response following prescribed burning.

Selection of areas with moderate coverages of sagebrush (10 to 15 percent) and in high fair to good ecological status will respond favorably in most situations. Sites in low seral ecological status are more rapidly reoccupied by sagebrush seedlings, more susceptible to annual plant invasion, and respond to a lower percentage increase of herbaceous production following sagebrush removal than those sites in mid or high seral ecological status (Hyder and Sneva 1956; Hedrick and others 1966).

The amount of sagebrush that results in reduced herbaceous production varies by site and sagebrush species. Sagebrush coverages of 10 to 15 percent will reduce herbaceous production significantly (Tisdale and others 1969).

A brief inspection of the site prior to burning will determine whether or not desirable plants are present in a density that will allow good postfire response. In some areas sagebrush coverages greater than 15 percent are desirable for certain species of wildlife (Klebenow 1972). In these instances one may decide to permit sagebrush coverage to increase to higher levels before considering burning to regenerate the stand. If so, remember this may slow the reestablishment of perennial plants following the burn. It should also be noted that the maximum potential cover of sagebrush varies considerably by species and site (table 2).

Season of the Year

Considerable work has been done on the effects of burning at different seasons (see summary by Wright and Bailey 1982). In general cool season grasses such as bluebunch wheatgrass are least detrimentally affected by fall fires, and warm season grasses such as blue grama are least affected by spring burns. In areas where the two occur together, the season of burning will favor one type of grass over the other (Gartner and Thompson 1972; Schripsema 1977; Wright and Bailey 1982). Seasonal effects are related to the phenological stage of the plant. These stages may vary regionally, yearly, and with elevation.

In the northern portion of the sagebrush range, the effect of season is less clear. Most communities in the northern Great Basin have no warm season grasses, so this aspect is of less consequence. The reported results of spring versus fall burns are mixed (Kuntz 1982; Wright and Klemmedson 1965; Wright and others 1979). In our experience, the perennial herbaceous species are most resistant if they are burned when completely dormant. In much of the Great Basin, spring fires are frequently not feasible due to the abundant moisture in late winter and spring. By the time the fuels dry out sufficiently, the new herbaceous growth is too advanced. This raises the fuel moisture to a point that fire will not carry through the combined living and dead fuels. If fires do occur, perennial grasses may incur high mortality. In eastern Idaho and Montana, however, proper fire conditions may occur in late winter (February-March). Fire response of herbaceous vegetation on these burns has been positive (Kuntz 1982). When the burns are delayed until after winter dormancy is broken, the effects can be much different, particularly on the fire-sensitive species such as Idaho fescue (Beardall and Sylvester 1976).

The same situation may occur in the fall. For instance, on the Owyhee Plateau, sufficient precipitation may occur in late summer or early fall to cause a fall green-up. Burning after this occurs seems to cause as much or more plant mortality as burning in the late summer when the plants are dormant.

Figure 6—A site classified as an *Artemisia tridentata wyomingensis/Agropyron spicatum* h.t. that contains little fine fuel in the understory. A community such as this would be difficult to burn and would not produce enough perennial grass forage to justify the cost of burning.

Table 2—Mean percent coverage for species of sagebrush by series for the northern Great Basin and Columbia River drainage; cover is estimated by the use of line-intercept method except as noted

	Source of data and State							
	Eckert 1957 (Oregon)	**Sheehy 1975 (Oregon)**	**Champlin 1982 (Oregon)**	**Winward 1970 (Idaho)**	**Clifton 1981 (Idaho)**	**Kuntz 1982 (Idaho)**	**Hironaka[1] (Idaho)**	**Daubenmire 1970[2] (Washington)**
Artemisia tridentata ssp. *wyomingensis*								
Mean	11	10		18	18		15	
Range	6-15	(approx) —		8-23	—		5-23	
n	13	3		13	20		48	
Artemisia tridentata ssp. *tridentata*								
Mean		13		24			9	15
Range		—		19-30			5-13	2-38
n		3		2			6	37
Artemisia tridentata ssp. *vaseyana*								
Mean	7	12	10	22		26	25	
Range	5-11	(approx) —	6-13	15-41		12-38	18-37	
n	7	3	8	21		15	17	
Artemisia tridentata ssp. *vaseyana* f. "*xericensis*"								
Mean		10					8	
Range		—					2-13	
n		3					7	
Artemisia tripartita								
Mean							11	21
Range							7-27	10-34
n							23	7
Artemisia cana								
Mean		28						
Range		—						
n		3						
Artemisia arbuscula								
Mean	15	11					13	
Range	8-19	(approx) —					6-20	
n	10	3					10	
Artemisia nova								
Mean		12					23	
Range		—					7-29	
n		3					26	
Artemisia rigida								
Mean							26	21
Range							7-60	10-34
n							26	7

[1]Unpublished data of M. Hironaka, University of Idaho.
[2]Coverages estimated with canopy coverage method (Daubenmire 1959).

Fires during early and midsummer are potentially the most damaging to plants. Bunting and others (1984) found that the mortality of bitterbrush was greater when the fires occurred in summer as compared to fall and spring. This is probably true for many other species, too. Repeated summer fires will often deplete a sagebrush-grass community of perennial grasses (Wright and Klemmedson 1965).

OBJECTIVES FOR PRESCRIBED BURNING

The objectives in using prescribed fire in the management of sagebrush-grass vegetation vary considerably, depending upon the vegetation and the particular resource that is being managed. But more than a single objective often can be achieved with a single burn (table 3).

The most common objectives of prescribed fires in sagebrush-grass vegetation are reduction of sagebrush cover and subsequent increase in herbaceous production. Harniss and Murray (1973) reported that by the third year following a fire grass and forb production on burned sites was greater than that on unburned sites, and this increased productivity continued for more than 10 years. After 30 years the mountain big sagebrush was beginning to become well established again and herbaceous production had declined to the unburned level. It has been found that minor amounts of sagebrush may affect herbaceous productivity. As sagebrush cover was reduced from 15 percent (untreated) to 8 and 0 percent, understory dry matter production increased from 194 lb/acre to 253 and 830 lb/acre, respectively (Tisdale and others 1969).

Herbaceous productivity, however, may not always increase following fire. On a mountain big sagebrush site in central Idaho, no significant increase had occurred during the first 3 years following fire. Sagebrush canopy cover on the site averaged 15 percent. The potential increase may be related to a number of factors, including plant vigor, subsequent growing conditions, site productivity, and sagebrush cover prior to treatment.

In some situations the objective may be not only to increase herbaceous productivity but also to increase the production of desirable forbs. Forbs are often seasonally important in the diets of many animals such as elk, pronghorn antelope (Miller and Vavra 1982), and domestic sheep (Stoddart and others 1975). Fire has been successful in achieving this in many situations. But not all sagebrush communities have equal potential for forb response. For example, Wyoming big sagebrush communities normally have small amounts of forbs, regardless of the ecological condition or successional stage.

Fire can prevent the invasion of other species into sagebrush-grass vegetation. In many areas sagebrush communities are being invaded by conifers such as juniper, Douglas-fir, and ponderosa pine. As these conifer stands develop, the productivity of the understory herbaceous species is reduced (Arnold and others 1964; Barney and Frischknecht 1974), making control of coniferous species often desirable.

Sagebrush may reach a size and density that physically impedes access of animals to the understory plants of the community. This may be common in communities of taller sagebrush species such as basin big sagebrush or with the species that may develop high coverages such as silver sage or mountain big sagebrush.

Mature sagebrush plants decline in productivity and become decadent with age. Because sagebrush is an important component in the diet of wildlife species, the establishment of young vigorous plants is a factor in wildlife management.

Table 3—Potential objectives for prescribed burning sagebrush/grassland vegetation

Objective	Duration of treatment	Citation
	Years	
Reduce sagebrush cover:		
mountain big sagebrush	15-25	Harniss and Murray 1973; Kuntz 1982
Wyoming big sagebrush	25-50	Blaisdell and others 1982
threetip sagebrush	10-20	
Increase herbaceous productivity	3-30	Harniss and Murray 1973; Wright and others 1979; Blaisdell and others 1982
Increase forb productivity	1-10	Harniss and Murray 1973
Increase sagebrush productivity		Hironaka and others 1983
Increase habitat diversity and edge effect (ecotone)		Lyon 1978
Reduce invasion by conifers		Wright and others 1979; Gruell and others 1986
Alter herbivore distribution		Klebenow and Beall 1977; Lowe and others 1978
Enhance palatability and nutrient value		Hobbs and Spowart 1984; Seip and Bunnell 1985
Seeding pretreatment		Monsen and McArthur 1985

The diversity of habitats available for wildlife is often a concern to management agencies. Successive fires have the potential to create mosaics of varying successional stages within an area (Lyon and others 1978). This increase in the diversity of habitats (beta diversity) and increase in the diversity of species present (alpha diversity) can often be a primary objective in prescribed burning in sagebrush-grass vegetation.

Prescribed fire has also been used as a control measure for sagebrush prior to seeding rangelands by aerial broadcasting or drilling. In addition to controlling sagebrush, the fire also consumes the majority of the woody biomass, improving access for equipment.

PLANNING PRESCRIBED FIRE

Development of Objectives

The initial step in considering the use of a prescribed fire is to identify the factor that is limiting productivity. For example, the grazing allotment may be limited by the forage available in just one unit. If the forage production of that unit were increased, the use of the entire allotment would be improved. Or perhaps the scarcity of forbs renders an area of limited use to one or more species of wildlife. If forb production were increased, the potential habitat for these species would be improved.

Once a limitation is identified, alternatives to improve the situation may be considered. Prescribed fire may often be one of these alternatives. Prescribed burning should not be a substitute for good range management. A problem rooted in inappropriate range management practices may not be corrected by vegetation treatment. In these instances management should be altered prior to application of prescribed fire. A preferred alternative will then be selected based on an onsite evaluation by a multidisciplinary team that considers economic, environmental, and other considerations. The authors assume that this portion of the planning process has occurred and that prescribed fire has been selected as the preferred alternative.

An important initial step in the fire plan development is focusing general objectives into specific objectives for a particular fire. The difference between a fire plan and a fire prescription should be noted. The fire plan is designed to direct practitioners through the planning sequence and includes such aspects as site characteristics, management objectives, and expected fire effects. The fire prescription specifies the environmental conditions, the desired fire behavior, and the accomplishment to be achieved by the fire (Fischer 1978). More specific objectives are necessary to determine the specific location and habitat type, and the characteristics of the fire desired, such as season, fire intensity, fire severity, and size of the area to be burned. Frequently, objectives such as "to improve wildlife habitat" or "to control sagebrush" are listed. General objectives such as these give little guidance to people developing a fire plan or the means to evaluate the success of achieving the objectives.

To overcome this problem, very specific objectives are sometimes developed for some fire plans. An example might be "to increase the production of bluebunch wheatgrass 200 lb/acre." The difficulty presented here is the considerable time commitment for intensive monitoring needed to determine whether or not the objective was achieved. It is important that objectives set be both realistic and attainable. (See Evaluation and Monitoring.) Site-specific objectives have been defined as:

A clear, concise statement of what is to be accomplished which:

(1) allows a reasonable opportunity for success;
(2) has an acceptable time frame for determining results;
(3) contains a measurable factor that determines the degree of success.

It is desirable to state objectives concisely enough to give guidance to those planning, conducting, and evaluating the fire, but at the same time, be reasonable in what this requires in evaluating the fire's success or failure. A desirable objective in this case would be "to increase herbaceous production 50 percent by the end of 3 years."

Frequently, more than one objective may be achieved with a single fire. A prescribed fire may initially increase forb diversity and production for pronghorn and later increase perennial grass for livestock. Problems arise when objectives conflict in the type of fire needed or the type of area to be burned. For example, if a burn is designed to provide greater amounts of herbaceous forage for elk in early spring, south-facing slopes may be burned on ridges free of snow early in the spring. But if a second objective is to increase production of grasses for cattle, the location and size of the burn may need to be changed. In some cases objectives may need to be prioritized.

Selection of Fire Area

Selection of the area to be burned will dictate how the fire can be conducted, characteristics of the fire, and whether it achieves its objectives. Areas with more than 1,500 lb/acre of fine fuels may be burned with a wide variety of fire prescriptions. Those with less than 500 lb/acre will be able to sustain fire only under warm temperatures and low relative humidities. The narrow range of potential burning conditions may limit achievement of objectives. As discussed earlier, the composition will affect the response of the area to the fire and may also limit the potential of fire to meet objectives.

The planning team needs to look at the proposed site, discuss its potential and any constraints or problems, and agree that the proposed objective can be met by use of prescribed fire. On many sagebrush-grass sites, fuel quantity is marginal for large fires (greater than 50 acres) under normal prescribed burning conditions. Beardall and Sylvester (1976) report that sagebrush in Nevada is difficult to burn if the herbaceous fuels are less than 600 lb/acre. But wildfire may occur on areas with less than 300 lb/acre (Wright and Bailey 1982). Sagebrush canopy coverage will compensate for the lack of fine fuels to some degree. Britton and Ralphs (1979) doubted that successful prescribed fires could be conducted on areas with less than 20 percent canopy coverage of sagebrush. Brown (1982) suggested that with 20 percent sagebrush cover, it would be necessary to have a minimum of 300 lb/acre of cured fine fuel and 10 mi/h of wind for successful fire spread. These minimum values preclude the use of fire in many areas of sagebrush-grass vegetation (table 2).

Areas with sagebrush coverages greater than 30 percent may burn even though the fine fuels are less than 300 lb/acre. This may occur if the sagebrush coverages are high and the fire can burn primarily through the sagebrush canopies. Postfire response of perennial grasses and forbs may not be as defined, however, unless adequate populations of preferred species populate the burned site.

The minimum amount of cured fine fuel needed varies with the type of species that comprise this component. Fine fuel primarily composed of tall perennial bunchgrasses such as needle-and-thread must be present in greater quantity than if the fine fuel is composed of annual grasses such as cheatgrass. The smaller particle size and even distribution of the annuals create a more uniform fuel bed enabling the fire to carry across areas with very low fine fuels.

Other factors that determine whether or not an area will burn include topography, slope, windspeed, sagebrush canopy moisture levels, and sagebrush height. As height and slope increase, the maximum distance that a flame is able to ignite fuels on a horizontal plane also increases ("fire reach," as defined by Neuenschwander 1980). This reduces the amount of sagebrush cover and fine fuels needed compared to the same type of fire in shorter sagebrush and/or on level terrain. The increased height of sagebrush may not necessarily contribute to fire spread, however, if it has a growth form with few lower branches.

Rough topography and slope also channel wind and create situations of upslope and downslope winds. These in turn increase the effective windspeed and enable one to burn at a lower average windspeed and lower fuel loadings than one can on level terrain.

The majority of the sagebrush fuels will be alive and therefore more moist than the fine fuels, which will probably be dormant at the time of burning. The big sagebrush subspecies remain physiologically active throughout most of the year (Campbell and Harris 1977; DePuit and Caldwell 1973; Fernandez and Caldwell 1975). Immediately following significant precipitation (0.25 inches or greater), we have noted increased moisture content in sagebrush foliage. Canopy moisture will reach or exceed the moisture of extinction, preventing the sagebrush from contributing to the fire spread. The fine fuels will dry out more quickly than foliage; therefore it may be possible to burn the fine fuels beneath the sagebrush plants. If sufficient fine fuels are present, it may be possible to kill the sagebrush plants, but they will not contribute significantly to fire behavior. Dry sagebrush canopies are necessary to burn sites with marginal fuels.

In addition to amount of fuels, one must consider fuel arrangement and continuity. Many sites, particularly those where fuel is marginal, are broken by areas with little fuel or vegetation types that produce little fine fuel (fig. 7). Such fuel patterns frequently prevent the spread of the fire over a large area and may be advantageous or disadvantageous, depending on the type of burn that is desired. Fuel discontinuity will, however, increase the cost per unit area burned and reduce the acreage that can be burned during a single burning period.

Preparation of a burning plan involves establishment of primary and often secondary control lines. The costs of the fire and the risks of escape can be significantly reduced if the area selected offers roads and natural breaks

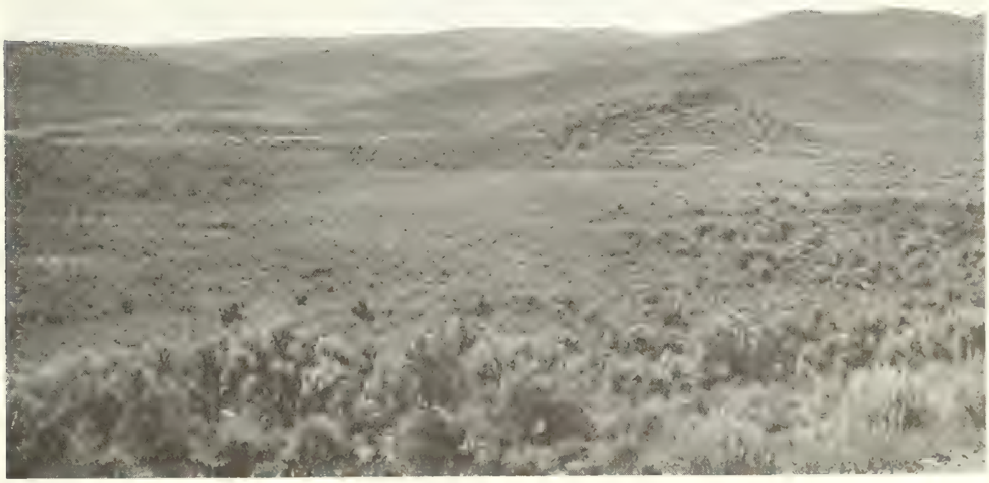


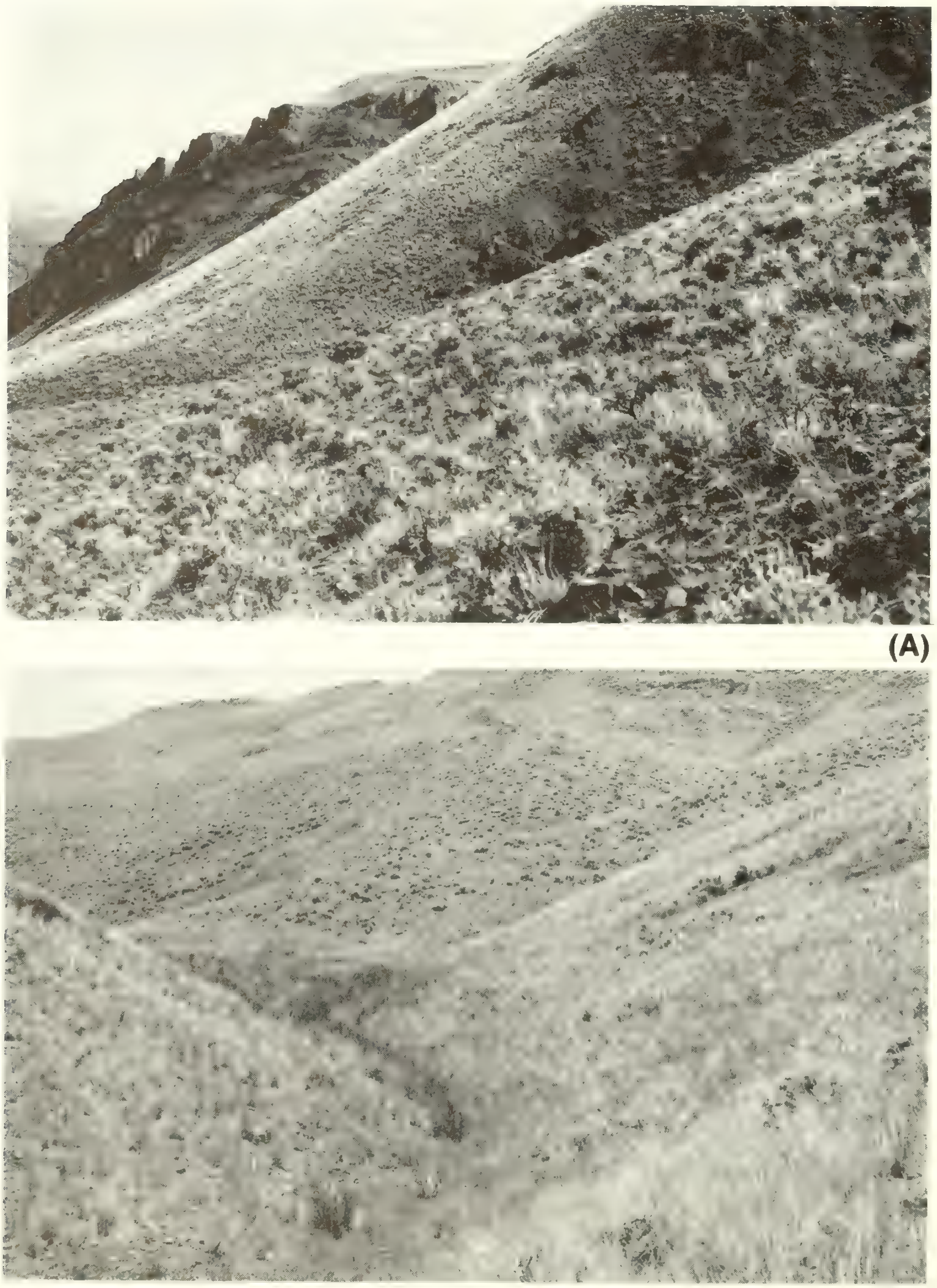
Figure 7—Vegetation types such as *Artemisia arbuscula/Festuca idahoensis* h.t.'s produce low amounts of fine fuels and may serve as firebreaks. The big sagebrush communities that are mixed with low sagebrush communities, such as above, may be burned with only minor fireline preparation. But caution is advised during years when above-average grass production may carry fire.

such as ridges, drainage ways, talus slopes, and less flammable vegetation types (fig. 8). The primary costs of prescribed burning are often associated with establishment of control lines.

Prescribed burns often require some type of special management before and following the fire. Any changes in management must be considered at the time of site selection. This management must be coordinated for all resource uses. For example, a fire designed to increase spring forage for deer may not require special management. If livestock have access to the burn, however, the full benefits of the prescribed fire may not be realized and negative impacts may occur unless management of the livestock is included in the plan.

Season of the Year

The season during which a tract is burned influences both the feasibility of burning and subsequent effects. The abundant precipitation renders burning impractical during late winter and spring throughout most of the northern sagebrush-grass region. By the time the previous year's



(A)

(B)

Figure 8A and B—Topography can often be utilized as firebreaks to minimize fireline preparation.

herbaceous fuels dry out, herbaceous plants have broken dormancy and have begun to produce green material. Range burning is unfeasible or undesirable at this time of year.

Burning during the fall is more common throughout most of the northern Great Basin. As a general rule, fall will offer more suitable burning days than spring. Because fine fuels and sagebrush canopies are drier, it is possible to burn sites that have less fuel. Some problems may be encountered, however. Areas such as the Owyhee Plateau may start to receive intermittent precipitation during this time of year. This often results in a fall green-up and an increase in the canopy moisture of sagebrush. Either occurrence will decrease the likelihood of conducting a successful burn when fuels are marginal.

Many managers are now considering conducting prescribed fires in late summer when the perennial grasses are dormant. By starting earlier, they can maximize the number of burning days available to them. In addition, the drier conditions may enable them to burn areas with lower accumulations of fuel. Starting earlier also enables managers to utilize seasonal personnel for prescribed burning projects. It must be recognized, however, that burning during the summer includes a greater probability of fire escape than burning during wetter and cooler seasons and the effects on the plant community may also differ.

In some areas, however, such as eastern Idaho and eastern Montana, late winter and early spring may favor prescribed burning. Drier weather and greater fine fuel loads of this region make burning at this time of year effective and economical. Burning sagebrush-grass vegetation that is mixed with forest vegetation can safely be attempted without firelines in these areas. The forests and drainages will retain the snow and make effective fire breaks. Fires conducted during late winter are often of low severity and tend to be small and patchy (Gruell and others 1986). This may be ideal to meet some objectives but may make burning large continuous acreages difficult.

Due to high moisture and snow-compacted fuels, spring fires are usually smaller and contain more unburned patches than fall fires. This may be either an advantage or a disadvantage, depending on the objectives of the project. Throughout most of the northern sagebrush-grass range, it is difficult to burn effectively in either spring or very late fall. Weather and fuel moisture will meet prescriptions (see page 9) on relatively few days.

Prescribed burns during spring or late fall should be considered special projects. The fires will be limited in size and effectiveness and should be compatible with objectives. Generally, sites with south and southwest aspects and at least moderate slope will be the most advantageous locations. Usually, fine fuels must be more abundant than during a drier season to achieve similar results.

During the spring, snow lines and increased fuel moisture on varying aspects adjacent to the proposed treatment area may aid in fire control and reduce overall cost. The limited burn size, however, may increase the amount of time and personnel required for ignition. In many cases, this results in higher average costs per acre. During these seasons, the limited days in prescription also often result in failure to achieve objectives.

Your particular geographic area should be studied to determine how many days will be in prescription on the average. If only a few days are likely to be in prescription, then modification of the plan may be necessary. United States Weather Service records and RX WTHR/RX BURN programs (Bradshaw and Fischer 1981a, 1981b) will be useful in obtaining and analyzing this information.

Size of Prescribed Fires and Fire Mosaics

The proposed size of a prescribed fire needs to be carefully considered during the planning process. The total acreage burned has a considerable effect on the postfire response of the vegetation. Wild and domestic animals are drawn to recently burned areas (Komarek 1969; Kramp and others 1983; Lyon and others 1978), resulting in greater utilization of the burned area than the surrounding vegetation. Water availability on the burned site may also concentrate utilization. Sufficiently large areas should be burned, so that browsing and grazing does not adversely affect the plants on the site.

Consideration should also be given to the amount of area that can be burned in a single burning period (normally 4 to 6 hours). Time will be needed to widen out firebreaks and ignite the unit. Sufficient time should be allowed for the unit to burn out prior to burning conditions becoming too cool and/or wet at night or too severe. In continuous fuels this limits the maximum size to about 500 to 2,000 acres when hand firing, and 1,000 to 3,500 acres when aerial ignition is used. Areas larger than this can be divided into smaller units. For noncontinuous fuels, the size of the individual fires is limited by variations in fuel loads.

Economics is also a factor in determining size of prescribed fires. The costliest portion of conducting prescribed fires is establishing and burning out fire lines. The smaller the size, the greater will be the perimeter per unit area. Over very large areas the need for (and costs of) additional personnel and equipment may outweigh the economics of burning larger units unless adequate natural barriers can be located.

Many prescribed burns are conducted with the objective of increasing the diversity of successional stages within an area or creating a fire mosaic. To do so, the size of the individual burned area should be small, usually less than 40 acres. Creating a mosaic of burned and unburned areas is relatively easy on sites with noncontinuous fuels and relatively high fuel moistures by careful selection of ignition pattern and weather conditions. Conditions are chosen in which only the sites with greater amounts of fuel will burn. As fuels become very noncontinuous and the topography becomes dissected, it is difficult to achieve a burn that is not a mosaic in spite of any fuel moisture relationships. A problem may arise, however, in areas where fuel loadings are high and more continuous. Without natural fuel breaks, an extensive system of fire lines may have to be established to restrict the fires to the desired size. This often makes the prescribed burn economically unfeasible. In these cases a compromise must be made between numerous small burns and a single large burn.

Rest and Deferment

There is a great deal of disagreement concerning the need for rest and deferment of grazing livestock on prescribed burns. The amount of nonuse necessary after the fire varies considerably with the vegetal composition, site conditions, and objectives of the burn and therefore may contribute to the controversy.

In almost all situations in the northern sagebrush-grass region, the prescribed burn area must be rested the year prior to the fire to permit the fine fuels to accumulate. Even light grazing often removes enough fuel to make fire spread difficult. Light grazing will break fuels continuity because animals will utilize preferred species and preferred sites first.

Land managers have often permitted light grazing in the spring, depending on fall regrowth to produce the fine fuels necessary for burning. In most instances regrowth was not sufficient. As a result, fires were patchy, or would not burn at all. There is some indication, however, that light grazing could be used to produce a patchy burn and create a mosaic in continuous fuels.

The amount of nonuse required after the fire depends upon many factors. Those prescribed burns that have a primary objective of increasing herbaceous production for livestock require some nonuse. Wright and others (1979) suggest that the area be ungrazed for two growing seasons in order to allow the perennial plants to recover from the fire. Currently, many land managers rest the burns the first year following the fire and then defer the second year. Grazing the established plants after dormancy in the fall probably has little effect on the plant if it is not utilized heavily. Resting the burned areas a year prior to the fire and for 2 years after the fire often makes it difficult to continue using traditional grazing systems. More use is shifted to unburned pastures, and consequently these may suffer during this time.

The ecological status of the burned unit affects postfire management. Pastures that have an adequate density of desirable plants present after the fire need only be ungrazed until those plants regain vigor. Areas with less than desired plant densities require postfire management that will maximize seed production and seedling establishment.

Other burn objectives need little or no special postfire livestock management. For example, an area was burned to enhance early spring forage for elk. The site was a south-facing slope near the crest of a high ridge. Due to the lack of water and steepness, livestock did not frequent the site. Grazing was deferred the year following fire so no adjustment in the grazing system was necessary. Because of improved palatability of forage cattle use increased on the burned site but did not become significant.

Prescription Development

Developing the fire prescription can determine to a large measure the probable success or failure of the fire. General procedures for planning prescribed fires have been developed by Fischer (1978) and Martin and Dell (1978). Special factors need to be considered when planning burns in sagebrush-grass and other vegetation types that produce low amounts of fine fuels.

The ranges in three weather factors suggested by numerous sources (Britton and Ralphs 1979; Wright and Bailey 1982; Wright and others 1979) are:

relative humidity 15-35 percent
temperature 60-85 °F
midflame wind 4-15 mi/h

Gruell and others (1986), and Bushey (1986) discuss fire prescriptions in relation to fuel conditions and prescribed fire objectives.

In sagebrush-grass fuels, the single most important prescription element is windspeed. Greatest changes in flame lengths and rate-of-spread came from changes in windspeed. Hence, considerable attention needs to be given to this element in both planning and implementing a burn. Additional factors to be included are (1) period of time since last significant precipitation, (2) atmospheric stability, and (3) the location and possible arrival of weather fronts. When the relative humidity is greater than 30 percent, the temperature is less than 60 °F, and the midflame windspeed is less than 4 mi/h, it is unlikely that fire will spread satisfactorily unless fine fuels exceed 600 lb/acre. When the relative humidity is less than 15 percent and the temperature is greater than 85 °F, fire control becomes more difficult. Windspeeds greater than 15 mi/h not only create fire control problems but also limit the effectiveness of fire within the burn area. At high windspeeds, the lateral spread of the fire is limited, and long narrow stringers of burned areas result. In some cases, these winds may actually blow the fire out (Neuenschwander 1980). In our experience, burning during windspeeds greater than 15 mi/h has never aided achieving a more continuous burn on an area.

As discussed earlier, fuel quantities, topographic conditions, and burn objectives may require that the prescription be modified within general limits. With small amounts of fine fuels and/or sagebrush cover, lower relative humidity (12 to 25 percent) and higher temperatures (75 to 85 °F) will be needed to enable the fire to spread. When fine fuels exceed 1,500 lb/acre, days with cooler temperatures, lower windspeeds, and higher relative humidities may be used to achieve a successful burn. Slope will increase the rate of spread significantly as graphically shown in Albini's (1976) nomographs. Brown (1982) estimated that a 30 percent slope will increase the rate of spread twofold to threefold over a level area and that a 50 percent slope will increase the rate of spread fourfold to sevenfold. More importantly for prescribed burning, steeper slopes will often enable the fire to carry across areas that would not burn if they were level by increasing the effective fire reach. Slope does not significantly affect the general range of temperature and relative humidity. Slope does, however, reduce the need for wind, and allow areas with lower fuel loads to be burned effectively. Even slopes of 10 to 15 percent may significantly affect fire rate-of-spread. See Albini (1976), Brown (1982), and Rothermel (1983) for further information on predicting fire behavior.

Other factors may also require deviation from the general fire prescription conditions. If burned and unburned mosaic is an objective, a prescription with cooler and moister weather conditions may be used. Conversely, significant amounts of green herbaceous growth (live fuels)

increase the average moisture content of the fine fuels, and a prescription requiring higher temperatures and lower relative humidities is needed.

Rate-of-spread, fire intensity, and flame length can be estimated by Rothermel's fire behavior model (1972) and by Albini's nomograms (1976). Rothermel's models have recently been adapted for use within a set of interactive computer programs for minicomputers (BEHAVE System, Burgan and Rothermel 1984; Andrews 1986) and personal microcomputers (PC/BEHAVE, Cooney 1986). These technical aids provide rapid evaluation of site specifics or NFFL fuel models, and predict fire behavior.

A program module for the Hewlett-Packard HP-71B calculator providing fire danger and fire behavior computations is also available for use in the field (Burgan and Susott 1986; Susott and Burgan 1986). This module replaces a similar one using the Texas Instrument TI-59 (Burgan 1979). Fire behavior models are primarily used for wildfire situations, to predict free-running headfires in a uniform environment. Although these models were not designed for prescribed burns, where fire behavior is influenced by ignition pattern, those who understand the models can use them to predict behavior of a prescribed burn. These computer programs are also useful in determining the need for suppression forces. If the fire behavior and spotting potential is great, the need and placement of suppression personnel and equipment becomes critical.

Other measurements of burning conditions have been developed and used in some situations. Fine fuel moisture has been used, but it is strongly correlated to relative humidity and temperature, which are far easier to obtain. Ten-hour time-lag moisture, which can be taken onsite with fuel moisture sticks, gives an index of the moisture of the 0.25- to 1.0-inch dead fuels. Although this size class of fuels is not abundant in sagebrush-grass vegetation, it may be used as a general index to the "dryness" of the system. Our experience shows that 10-hour time-lag moisture should be less than 10 percent and preferably near 8 percent. When the 10-hour time-lag is less than 7 percent, the sagebrush twigs and branches are completely consumed by the fire. More research needs to be done on the application of this index to rangeland burning. The moisture content of the current year's growth of sagebrush is an index to the flammability of these plants. Results have been highly variable, but preliminary data indicate that the moisture content should not exceed 110 percent of dry weight for most situations.

Many prescriptions call for a significant amount of rainfall to occur prior to the fire's ignition. Although this may enhance resprouting of some shrubs such as bitterbrush (Blaisdell and Mueggler 1956), it may also create undesirable effects. In many areas of the northern Great Basin and Columbia Basin, late summer and early fall are characterized by warm dry weather. Precipitation does not often occur until the general high pressure over the area breaks down. Once this happens, periodic showers occur and cooler temperatures predominate until winter. A situation is created where the weather seldom gets into the general range of sagebrush burning prescriptions. This is particularly critical in areas with marginal fine fuels (and less topographic relief) where conditions on the drier and warmer end of the general range are needed. Many prescribed fires end up being very patchy and small or have had to be postponed because wet conditions prevailed after this precipitation occurred. The need for precipitation prior to burning to achieve the desired fire effects and the likelihood of adequate burning conditions afterward should be critically assessed before writing the fire prescription.

Other Factors To Be Considered

During the planning process a number of other factors should be considered to maximize the probability of a successful burn. Most sagebrush-grass vegetation must be rested prior to burning to allow fine fuels to accumulate. This is a management cost that cannot be recovered unless the grazing system included a rest for that area at that time. The possibility of a year occurring where conditions are not optimum for burning as described in the plan should be considered. It is well known by those conducting prescribed burns that all years are not equal and that we have so-called "good years" and "bad years." Bad years may include years during which the precipitation is so limited that the fine fuels are significantly less abundant than expected. They may also be years wherein precipitation occurs throughout the summer and the herbaceous fuels never cure completely prior to winter. In other years, the fall rains may begin earlier than expected and the fuels never dry sufficiently.

These conditions may result in fires that achieve far less than desired. A manager is faced with choosing between three options:

1. Rest the area a second year and postpone the fire for 1 year;
2. Due to allotment limitations one cannot delay the fire for 1 year and consequently the fire may be postponed indefinitely;
3. Decide to burn under current conditions, realizing that the objectives will not be met as successfully as hoped.

Option 3 may result in less area being burned than desired if conditions are too wet. Less than desirable mosaics of burned and unburned vegetation may also result. The consequences of each alternative should be considered and guidance given to the personnel charged with conducting the fire.

The same type of reasoning must take place in regard to a single day. Most of the fire prescriptions for sagebrush-grass vegetation are very similar in the required weather conditions. As more and more fire projects are planned each year, the number of days in which fires can be conducted may become a limiting factor. This situation can be alleviated in several ways. More personnel can be trained to conduct prescribed burns, allowing more than one burn to be conducted on a given day. The conditions under which fires are prescribed may be expanded. This may involve (1) beginning the prescribed burning earlier in the summer, or (2) burning on days when conditions are less than optimal.

Both choices have included within them certain costs and risks. Burning under hotter and drier conditions increases the risk of escape and the need for suppression

Table 4—Suggested timetable/checklist for prescribed burning

Activity	Date to be completed
Development of burn plan	Year prior to burn
Sample monitoring plots	Growing season prior to fire
Install RAWS unit in field	
Reserve fire equipment, firing and holding crews	
Weather and fuel moisture monitoring	Begin 10 days prior to burn or as required
Prepare firelines	End of growing season prior to fire or immediately before fire
Inspection of firelines	Post-fireline preparation
Inspection of fire equipment, water sources to be used in fire	
Determine firing and holding burn pattern	Day prior to burn
Review burn plan with all personnel	Day of burn
Notify local fire departments	Day of burn
Monitor weather	Hourly day of burn
Sample vegetation and other monitoring plots	Yearly or as required
Evaluation of burn plan	Postburn

forces. Burning earlier in the summer may require wildfire suppression personnel who may not be as available for prescribed burning. Many plant species may not respond as favorably when burned during midsummer as during late summer and early fall. Burning under cooler and wetter conditions results in patchy, small burns and requires more personnel for ignition. Each situation may result in not fully achieving the objectives of the burn and add to the cost of the project. These possibilities should be considered well in advance of the fire so that personnel conducting the burns can deal with situations as they arise.

Prefire Activities

A number of other tasks need to be accomplished prior to the burn. In most areas other agencies need to be notified, and a burning permit may be required. The surrounding agencies, landowners, and fire departments should be notified of the date of the burn. This should prevent an alarm being issued to a fire suppression group.

A timetable-checklist should be developed for the project. This would cover the prefire jobs, who is to do them, and the completion dates. Typical duties would be the establishing of monitoring plots, prefire weather and fuels data, securing and testing of equipment, training of personnel, and notification of others (table 4).

Prefire Crew Briefing

An onsite briefing should be conducted prior to ignition. This is necessary for the success of the fire and safety of the personnel. The more complex the fire is and the larger the fire crew needed, the more the briefing is necessary. At this briefing the overall plan is outlined on a map so everyone understands the entire project. Each individual should be assigned a specific job. At this time an individual is designated to record periodic weather observations. If photographs or data are to be taken, such chores should be assigned to specific individuals. All personnel should be checked out on equipment they are to operate.

Personnel in charge of holding firelines need to be aware of critical points along the fire perimeter. The contingency plan in case of fire escape must be outlined. Location of water sources should be identified for all engine operators. Finally, escape routes for all personnel must be clearly identified.

The briefing must cover communication among personnel, which is often a major problem during the burn. The briefing must also cover actions in case of changing weather conditions. Unpredicted fronts may significantly affect weather. In addition, large fires may generate their own wind (Schroeder and Buck 1970). Contingencies for such events should be outlined to the crew.

EVALUATION AND MONITORING

Usually, the project will be evaluated to determine if it achieved objectives, and to foster improvement in planning implementations of other burns. Evaluations may vary from highly subjective and qualitative observation to sophisticated quantitative monitoring. The degree of evaluation required depends on the specificity of the objectives of the burn and the availability of data from the area.

As objectives become more specific, the evaluation becomes more painstaking. For example, it is much more difficult to determine whether or not the annual production of bluebunch wheatgrass increased by 100 lb/acre following a prescribed fire than it is to determine whether there has been a 50 percent increase in herbaceous production. Although the sampling methodology is similar, the

sampling intensity required is much less in the latter case. The availability of pertinent data may also affect the monitoring needs. In some situations information may be available so that only sampling of general trends will be necessary. In other situations, no literature or administrative studies may be available and more detailed sampling would be necessary.

Regardless of the monitoring effort needed, a number of requirements remain. For most types of data, the most efficient sampling procedure utilizes a permanent sample site. This reduces the amount of variability included within the site. The site should be sampled prior to the burn treatment in order to further account for between-site variability. By taking prefire measurements it is possible to detect smaller changes with lower sampling intensity than one can by randomly sampling burned and unburned vegetation after the fire has occurred. The establishment of a permanent site does not necessarily imply that the sampling microplots are permanently located. This will be addressed in more detail under the various sampling methods. The monitoring effort should be tailored to the objectives of the plan. Many monitoring programs involve studies that are not related to the objectives. Although the information may be useful, its collection adds to costs.

When sampling vegetation, a control or an untreated sample plot should be established and sampled at the same time as the treated plots. An untreated plot is needed to separate the effect of the yearly weather variation from the effect of the burn on the vegetation. It is essential that the environmental conditions of the untreated area reflect those of the burned area. Therefore, it is important to select sites that are as similar as possible in vegetation composition, soil type, and grazing impact. Sampling in subsequent years should also fall within the same general phenological timeframe as the original sampling. Untreated plots are particularly important when benefits of the prescribed fire will not be realized for more than 5 years after the site is burned. In these situations the untreated vegetation may also change significantly over time.

It is suggested that the agency's standard sampling procedure for determining range trend (vegetation change) be used if possible. This method can then be modified or added to in order to assure that the appropriate data needed are collected. Use of the agency's standard method simplifies documentation and provides for an additional range trend data point should it be needed in the future. Individuals or agencies without a standard procedure may want to adopt a method with which they are familiar.

Types of Vegetation Data

Vegetation characteristics that can be sampled are rather limited in number. The basic vegetation parameters are descriptors of a plant community and primarily include basal cover, foliar cover, species density, and species biomass. Frequency is another vegetation characteristic related to abundance. These methods have been described by Brown (1954), Mueller-Dombois and Ellenberg (1974), Pieper (1978), and Cook and Stubbendieck (1986). In addition to the basic vegetation descriptors mentioned above, it may also be necessary to monitor direct fire effects such as plant mortality and characteristics related to fire behavior such as fuel moisture.

We are not recommending inclusion of all types of data in a monitoring system. The amount and type of data needed vary, depending upon the prescribed burn objectives, the data available from other sources, the extent of the proposed burn, the value of the resources involved, and ability of the interested agency to commit funds and personnel. The following sections are intended to recommend procedures that have been utilized in the past to evaluate prescribed burns. These methods, when correctly applied, have supplied data of appropriate precision for land management purposes. Whenever possible, we encourage collection of both vegetal and fuel data on the same transects or plots.

Plant Cover—Plant coverage values can be used as an effective indicator of dominance in a community because they allow comparisons between species of varying growth forms (Mueller-Dombois and Ellenberg 1974). There are two basic forms of coverage: basal cover and foliar cover. Basal cover is a vertical projection of the root crown area onto the ground surface while foliar cover is the projection of the entire aerial portion of the plant. Foliar cover of herbaceous plants is more sensitive to changes caused by season, climate, and grazing than is basal cover. Basal cover is rarely estimated for shrubs because it inadequately reflects the importance of these species. Basal cover is also not usually estimated for annuals and single-stemmed or rhizomatous species because the unit basal area is smaller.

The most widely accepted method of determining coverage of herbaceous plants is through the use of point-intercept (Mueller-Dombois and Ellenberg 1974). Usually multiple points are taken at sample locations at a given interval along a tape. The point frame developed by Floyd and Anderson (1983) has been shown to give good results in sagebrush-grass vegetation, particularly for foliar coverage (fig. 9 illustrates a cross hair point frame). Basal coverage is more labor intensive. It is often preferable to obtain an estimate of basal cover from a more easily obtained characteristic such as frequency (discussed later).

Line-intercept is an efficient method for sampling shrub aerial coverage (Canfield 1941). The length of the individual lines required may vary but normally exceeds 25 feet in length. The lines should not be so long that they cross vegetation or soil types. Line-intercept has also been used with some success for herbaceous vegetation. It may be applied fairly well to sampling bunchgrasses but is very tedious and time consuming when sampling rhizomatous grasses or very small plants (Floyd and Anderson 1983). Different length lines are usually required to sample shrub and bunchgrass species. To solve this, only a portion of the total line length will be used to sample the herbaceous species. For the sake of consistency between observers, it is better to sample from one edge of the canopy to the other (fig. 10 shows line-intercept method). Only large gaps (greater than 8 inches) in the canopy are subtracted. Subtraction of small areas reduces replicability and adds to sampling and recording time required. Line-intercept and canopy coverage estimation (Daubenmire 1959) of shrub cover provide comparable results. But line-intercept is preferred where levels of high precision and confidence are required (Hanley 1978).

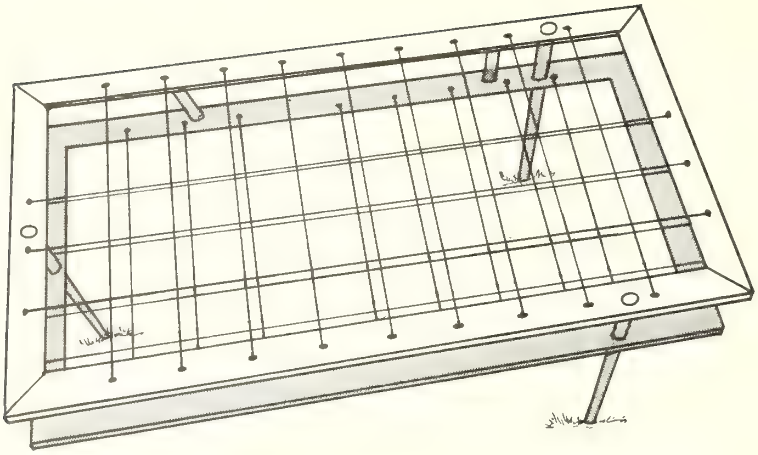


Figure 9—Point-sighting frame for estimating herbaceous foliar cover.

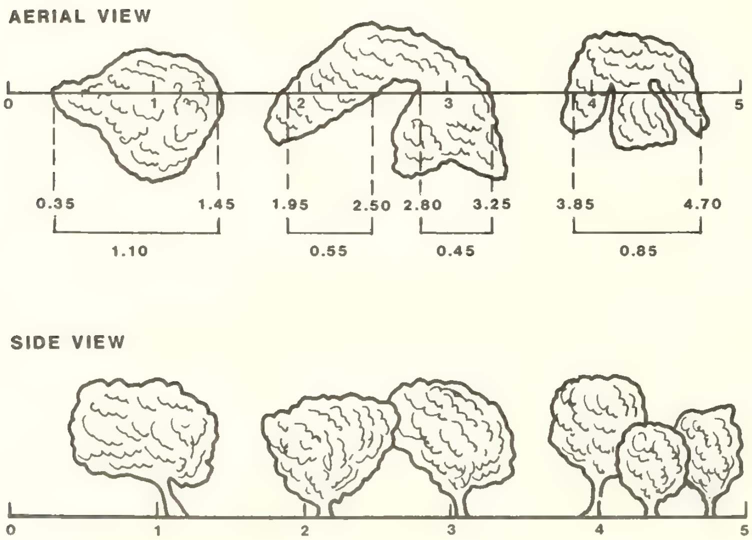


Figure 10—Line-intercept method for determining shrub cover.

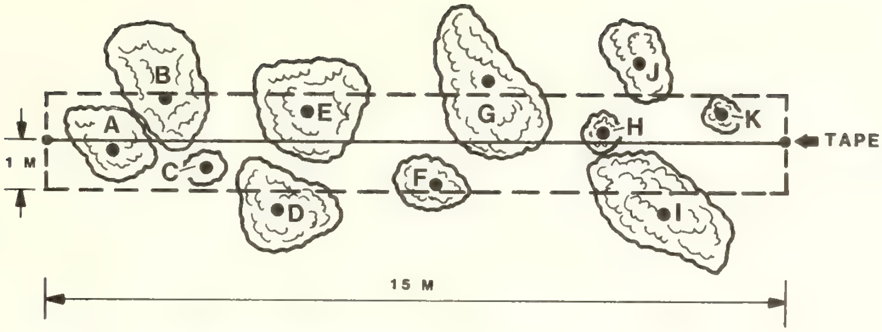


Figure 11—Belt transect layout for estimating shrub cover and density.

Plant Density—Although plants-per-unit-area is perhaps the easiest sampling method to grasp, it is difficult to apply (Mueller-Dombois and Ellenberg 1974). The number of plants does not accurately reflect the relationship between plants of different growth forms. The individual plant is difficult to determine when the species are rhizomatous or bunchgrasses whose crowns have begun to break up into smaller units. Also, sampling density may be very time-consuming for small and abundant species. Density measurements may be useful, however, for shrub species, particularly the nonrhizomatous species. The belt transect is an effective method of sampling shrub density (fig. 11). Only those plants rooted within the belt transect are recorded. Transects may be randomly established within a site. The length, width, and number will vary with the vegetation.

Plant Frequency—Frequency of occurrence is an effective method for detecting changes in composition in herbaceous vegetation (Smith and others 1986). Such surveys can be done rapidly and fairly consistently between observers because only species identification and whether or not the plant is rooted in the plot are required. Rooted frequency is directly related to basal crown cover and is therefore less sensitive to changes due to season, climate, and utilization by grazing animals than are many other descriptors such as foliar cover. Frequency has also been adopted by some land management agencies as the standard procedure to measure range trend.

In order for frequency to be sensitive to changes, the occurrence of an individual plant should be between 26 and 86 percent (Curtis and McIntosh 1950), preferably greater than 50 percent (Smith 1982). The size of quadrat required to give the desired frequency of occurrence varies with density, size of the average plant, and plant distribution. Preferred quadrat size varies among species. But we have found that the nested quadrat (fig. 12) gives adequate results for most species. Occurrence is recorded for all species in all plot sizes. Recording can be done rapidly by beginning with the smallest plot and adding individuals occurring in successively larger plots. Thus data for the correct plot size are recorded without extensive preliminary sampling.

The number of quadrats per site is an important factor if statistical analysis of the data is anticipated. Smith and others (1986) have shown that a minimum of 100 quadrats is necessary. Sensitivity will increase significantly up to

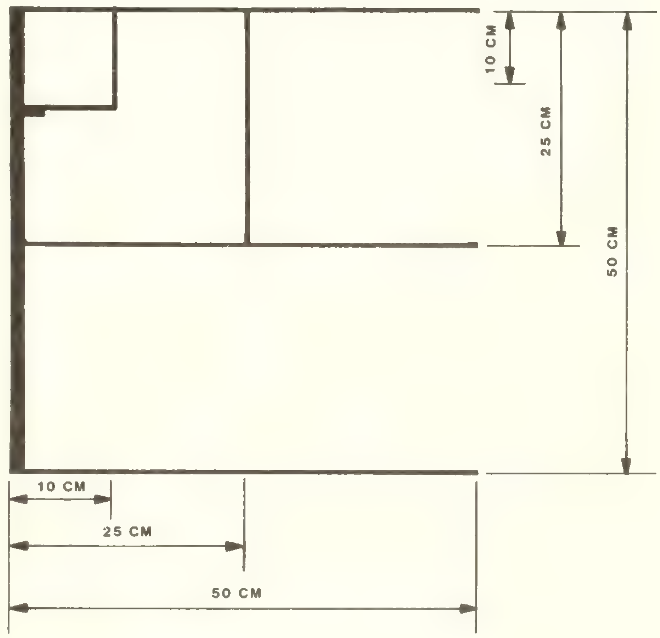


Figure 12—Nested frequency quadrat.

about 200 quadrats per site, with only minor increases in sensitivity thereafter.

The quadrats are usually placed at a predetermined interval along a tape. Using a tape to determine plot position reduces bias in placement of the quadrat. The interval between quadrats should be greater than the maximum size of the plants sampled, thus eliminating the possibility of an individual falling into two quadrats. An interval of 3 feet is adequate for sagebrush-grass vegetation. Quadrats should never be placed adjacent to one another.

Because many will not survive, seedlings of perennial plants often increase the variability between sample periods. It is usually best to not record seedlings until they are well-established or record them separately from the established plants. Frequency may also be used to estimate density (Greig-Smith 1983) and basal area.

Plant Mortality—Frequently land managers are interested in assessing the mortality of key species. This is most efficiently accomplished by locating populations and permanently marking randomly selected individuals with stakes. Locations of individuals can then be mapped in

reference to a witness marker (fig. 13). At least 20 individuals per species should be located. If the distance between individuals exceeds 15 feet for herbaceous plants or 30 feet for shrubs, relocation in future years may prove difficult. Mortality should be assessed for several years following the fire, particularly when sampling shrubs. Individuals may resprout but then die several years after the fire occurred (Bunting and others 1984; Clark and others 1982).

When permanent line transects are established for other sampling purposes, these may also be used to assess mortality of key species. Plant locations can be mapped in relation to distances along the tape (fig. 13). Plants should still be permanently marked with stakes. Stakes should be placed in the same location (for example, north side) and placed at the same distance from the plant base. Metal tags with stamped numbers have been found to work best. If a plant dies and disappears, it is difficult to determine whether mortality or a mismeasurement has occurred unless the location can be identified.

Plant Biomass—Determining productivity of herbs and shrubs is often desirable because it is directly related to carrying capacity. Unfortunately, sampling to determine productivity by species is most difficult. Great variability between plots requires a large number of samples. Mosley (1983) found that more than 50 samples were commonly required for major species. Total herbaceous productivity can be estimated more easily. Mueggler (1976) found that ten 4.8-ft^2 quadrats sampled total herbaceous production, with an 80 percent probability of coming within ± 20 percent of the mean in most Montana grassland and sagebrush-grass habitat types. Productivity estimates should be sampled at the same phenological stage each year, preferably after maximum standing production has occurred.

Herbaceous production should be sampled on a permanently located site. It must be remembered that the exact same area should not be clipped every year. The previous year's clipping will affect the next year's production.

Fuel Loading Measurements—The total fuel load may need to be estimated for prescribed burns. This may be particularly important at the onset of a burning program, to allow use of various fire behavior models (Albini 1976; Britton and Ralphs 1979; Brown 1982). Fine fuels may be

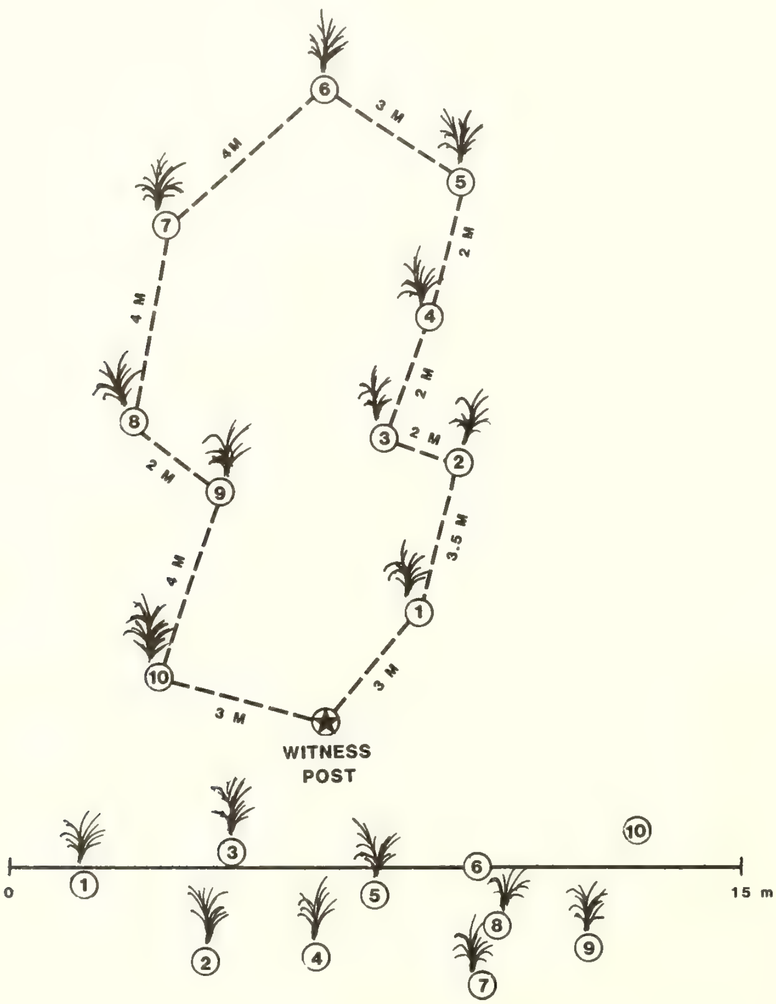


Figure 13—Two methods for locating permanently marked plants to determine mortality of key species.

sampled with the same procedures as used for herbaceous production. The only difference is that the litter must also be collected from the quadrats. Brown and others (1982) describe a less time consuming method, that utilizes a combination of clipping and weighing and weight estimation. Analysis is completed by an interactive computer program (FUELS), which provides mean loadings, standard deviations, and standard error as a percentage of the means.

The shrub component of the fuel load is also an important factor. The fine fuels and shrubs collectively determine whether or not the fire will spread. The lack of one may be partially compensated for by the presence of the other. The model by Britton and Ralphs (1979) used sagebrush cover as an indication of shrub fuel load. The combination of average sagebrush height and coverage is used in Brown's (1982) model. Frandsen (1983) utilized equivalent basal diameters to estimate shrub fuel loads. Shrub coverage can be estimated with the line-intercept, as previously described. Shrub heights can be recorded at predetermined intervals along the tape and then averaged to estimate mean height.

Burn Area—The total area burned can be estimated most effectively from the air. If precise estimates are required, aerial photographs can be taken after the fire, or the burn area can be mapped onto topographic maps, and the area estimated using standard dot grid or planimeter methods (Avery 1977; Colwell 1983). If aerial photographs are to be used, the scale of the photograph must be established.

Photography—Photographs can provide an effective means of documenting changes due to the prescribed burn. Permanent photopoints should be established at all vegetation sample locations. The photopoints should be carefully referenced and the major species listed. Closeup and oblique photos should be taken to illustrate ground details as well as overall community appearances.

Plot Layout

Many land managers may be unsure as to how to lay out and document a fire effects sample plot. Once data needs are determined, sampling should be done in a systematic manner that can be replicated in the future. We have

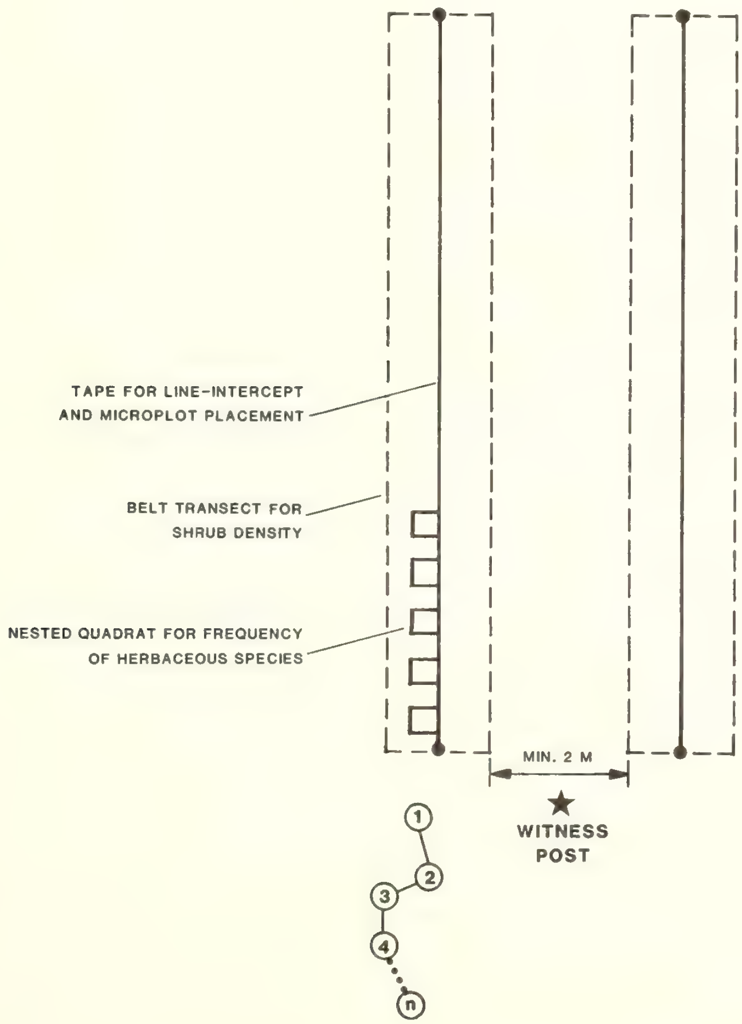


Figure 14—Suggested plot design for monitoring shrub cover, density, herbaceous species frequency, and mortality of key species.

established a system that has worked successfully in the past, although many modifications have also been used.

The system consists of a series of permanently established transect lines running parallel to one another (figure 14 shows sample plot layout as if all data previously discussed were being recorded). The length of the individual transects may vary between locations but should not cross vegetation or soil types. In most situations lines that are between 25 and 100 feet long seem to be appropriate in sagebrush-grass vegetation. The number of lines may also vary depending upon the length of each line. If a minimum of 100 frequency plots are sampled and they are at least 3 feet apart, this requires at least 300 feet of total transect length. This distance is also probably a minimum transect length from which to determine sagebrush cover. The parallel lines should be separated enough so that one line can be read without disturbing another.

REFERENCES

Albini, F. A. Estimating wildfire behavior and effects. 1976. Gen. Tech. Rep. INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 92 p.

Andrews, P. L. 1986. BEHAVE: fire behavior prediction and fuel modeling system—BURN Subsystem, part 1. Gen. Tech. Rep. INT-194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 130 p.

Armour, C. D.; Bunting, S. C.; Neuenschwander, L. F. 1984. Fire intensity effects on understory in ponderosa pine forests. Journal of Range Management. 37: 44-49.

Arnold, J. F.; Jameson, D. A.; Reid, E. H. 1964. The pinyon-juniper type of Arizona: effect of grazing, fire and tree control. Res. Pap. 84. Washington, DC: U.S. Department of Agriculture, Forest Service. 28 p.

Avery, T. E. 1977. Interpretation of aerial photographs. 3d ed. Minneapolis, MN: Burgess: 73-78.

Barney, M. A.; Frischknecht, N. C. 1974. Vegetation changes following fire in the pinyon-juniper type of west-central Utah. Journal of Range Management. 27: 91-96.

Beardall, L. E.; Sylvester, V. E. 1976. Spring burning for removal of sagebrush competition in Nevada. In: Proceedings, Tall Timbers Fire Ecology Conference No. 14; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station: 539-547.

Beetle, A. A. 1960. A study of sagebrush, the section Tridentatae of *Artemisia*. Bull. 368. Laramie, WY: University of Wyoming, Agriculture Experiment Station. 83 p.

Beetle, A. A.; Young, A. 1965. A third subspecies in the *Artemisia tridentata* complex. Rhodora. 67: 405-406.

Blaisdell, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains. Tech. Bull. 1075. Washington, DC: U.S. Department of Agriculture, Forest Service. 39 p.

Blaisdell, J. P.; Mueggler, W. F. 1956. Sprouting of bitterbrush (*Purshia tridentata*) following burning or top removal. Ecology. 37: 365-370.

Blaisdell, J. P.; Murray, R. B.; McArthur, E. D. 1982. Managing Intermountain rangelands—sagebrush-grass ranges. Gen. Tech. Rep. INT-134. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 41 p.

Bradshaw, L. S.; Fischer, W. C. 1981a. A computer system for scheduling fire use. Part I: the system. Gen. Tech. Rep. INT-91. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 63 p.

Bradshaw, L. S.; Fischer, W. C. 1981b. A computer system for scheduling fire use. Part II: computer terminal operator's manual. Gen. Tech. Rep. INT-100. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 34 p.

Britton, C. M.; Ralphs, M. H. 1979. Use of fire as a management tool in sagebrugh ecosystems. In: The sagebrush ecosystem: Proceedings of a symposium; 1979 April; Logan, UT. Logan, UT: Utah State University: 101-109.

Brown, D. 1954. Methods of surveying and measuring vegetation. Bull. 42. Bucks, England: Farnum Royal, Commonwealth Agriculture Bureau. 223 p.

Brown, J. K. 1982. Fuel and fire behavior prediction in big sagebrush. Res. Pap. INT-290. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.

Brown, J. K.; Oberheu, R. D.; Johnston, C. M. 1982. Handbook for inventorying surface fuels and biomass in the Interior West. Gen. Tech. Rep. INT-129. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.

Bunting, S. C.; Neuenschwander, L. F.; Gruell, G. E. 1984. Fire ecology of bitterbrush in the northern Rocky Mountains. In: Fire's effects on wildlife habitat: Proceedings of a symposium; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 48-57.

Burgan, R. E. 1979. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculator: user's manual. Gen. Tech. Rep. INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 25 p.

Burgan, R. E.; Rothermel, R. C. 1984. BEHAVE: fire behavior prediction and fuel modeling system—FUEL subsystem. Gen. Tech. Rep. INT-167. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 126 p.

Burgan, R. E.; Susott, R. A. 1986. Fire danger computations with the Hewlett-Packard HP-71B calculator. Gen. Tech. Rep. INT-199. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 16 p.

Bushey, C. L. 1986. Comparison of observed and predicted fire behavior in the sagebrush/bunchgrass vegetation type. In: Long, J. N., ed. Fire management: the challenge of protection and use: Proceedings; 1985 April 17-19; Logan, UT. Logan, UT: Utah State University: 187-191.

Campbell, G. S.; Harris, G. A. 1977. Water relations and water use patterns for *Artemisia tridentata* Nutt. in wet and dry years. Ecology. 58: 652-659.

Canfield, R. 1941. Application of line interception in sampling range vegetation. Journal of Forestry. 39: 388-394.

Cattelino, P. J.; Noble, I. R.; Slatyer, R. O.; Kessell, S. R. 1979. Predicting the multiple pathways of plant succession. Environmental Management. 3: 41-50.

Chaplin, M. R. 1982. Big sagebrush (*Artemisia tridentata*) ecology and management with emphasis on prescribed burning. Corvallis, OR: Oregon State University. 136 p. M.S. thesis.

Chaplin, M. R.; Winward, A. H. 1982. The effect of simulated fire on emergence of seed found in the soil of big sagebrush communities. In: Society for Range Management abstracts; 35th annual meeting; Calgary, AB, Canada. Denver, CO: Society for Range Management: 37.

Clark, R. G.; Britton, C. M.; Sneva, F. A. 1982. Mortality of bitterbrush after burning and clipping in eastern Oregon. Journal of Range Management. 35: 711-714.

Clifton, N. A. 1981. Response to prescribed fire in a Wyoming big sagebrush/bluebunch wheatgrass habitat type. Moscow, ID: University of Idaho. 39 p. M.S. thesis.

Colwell, R. N., ed. 1983. Manual of remote sensing. 2d ed. Falls Church, VA: American Society of Photogrammetry. 1019 p.

Connell, J. H.; Slatyer, R. O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. American Naturalist. 111: 1119-1144.

Cook, C. W.; Stubbendieck, J., eds. 1986. Range research: basic problems and techniques. Denver, CO: Society for Range Management. 317 p.

Cooney, T. M. 1986. Predicting fire behavior with microcomputers. Journal of Forestry. 84(5): 14-16.

Countryman, C. M.; Cornelius, D. R. 1957. Some effects of fire on a perennial range type. Journal of Range Management. 10: 39-41.

Curtis, J. T.; McIntosh, R. P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology. 31: 434-455.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concept of vegetation classification. Ecological Monographs. 22: 301-330.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science. 33: 43-64.

Daubenmire, R. 1970. Steppe vegetation of Washington. Tech. Bull. 62. Pullman, WA: Washington Agricultural Experiment Station. 131 p.

DePuit, E. J.; Caldwell, M. M. 1973. Seasonal pattern of net photosynthesis of *Artemisia tridentata*. American Journal of Botany. 60: 426-435.

Eckert, R. E. 1957. Vegetational-soil relationships in some *Artemisia* types in northern Harney and Lake Counties, Oregon. Corvallis, OR: Oregon State University. 208 p. Ph.D. dissertation.

Fernandez, O. A.; Caldwell, M. M. 1975. Phenology and dynamics of root growth of three cool semi-desert shrubs under field conditions. Journal of Ecology. 63: 703-714.

Fischer, W. C. 1978. Planning and evaluating prescribed fires—a standard procedure. Gen. Tech. Rep. INT-43. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 19 p.

Floyd, D. A.; Anderson, J. E. 1983. A new point interception frame for estimating cover of vegetation. In: Markham, O. D., ed. Idaho National Engineering Laboratory Radioecology and Ecology Programs 1983 progress report. Idaho Falls, ID: U.S. Department of Energy: 107-113.

Frandsen, W. H. 1983. Modeling big sagebrush as a fuel. Journal of Range Management. 36: 596-600.

Gartner, F. G.; Thompson, W. W. 1972. Fire in the Black Hills forest-grass ecotone. In: Proceedings Tall Timbers Fire Ecology Conference No. 12; 1972 June 8-9; Lubbock, TX. Tallahassee, FL: Tall Timbers Research Station: 37-68.

Greig-Smith, P. 1983. Quantitative plant ecology. Berkeley, CA: University of California Press. 359 p.

Gruell, G. E.; Brown, J. K.; Bushey, C. L. 1986. Prescribed fire opportunities in grasslands invaded by Douglas-fir: state-of-the-art guidelines. Gen. Tech. Rep. INT-198. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 19 p.

Hanley, T. A. 1978. A comparison of the line-intercept and quadrat estimation methods of determining shrub canopy coverage. Journal of Range Management. 31: 60-62.

Hann, W. J. 1982. A taxonomy system for classification of seral vegetation of selected habitat types in western Montana. Moscow, ID: University of Idaho. 235 p. Ph.D. dissertation.

Harniss, R. O.; Murray, R. B. 1973. Thirty years of vegetal change following burning of sagebrush-grass range. Journal of Range Management. 26: 322-325.

Harniss, R. O.; Harvey, S. J.; Murray, R. B. 1981. A computerized bibliography of selected sagebrush species (genus *Artemisia*) in western North America. Gen. Tech. Rep. INT-102. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 107 p.

Hedrick, D. W.; Hyder, D. N.; Sneva, F. A.; Poulton, C. E. 1966. Ecological response of sagebrush-grass range in central Oregon to mechanical and chemical removal of *Artemisia*. Ecology. 47: 432-439.

Hironaka, M. 1979. Basic synecological relationships of the Columbia River sagebrush type. In: The sagebrush ecosystem: a symposium: Proceedings; 1979 April; Logan, UT. Logan, UT: Utah State University: 27-32.

Hironaka, M.; Fosberg, M. A.; Winward, A. H. 1973. Sagebrush-grass habitat types of southern Idaho. Bull. 35. Moscow, ID: University of Idaho, Forestry, Wildlife, and Range Experiment Station. 44 p.

Hitchcock, C. L.; Cronquist, A. 1973. Flora of the Pacific Northwest. Seattle, WA: University of Washington Press. 730 p.

Hobbs, N. T.; Spowart, R. A. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. Journal of Wildlife Management. 48: 551-560.

Horn, H. S. 1975a. Forest succession. Scientific American. 232: 90-98.

Horn, H. S. 1975b. Markovian properties of forest succession. In: Cody, M.; Diamond, J., eds. Ecology and evolution of communities. Cambridge, MA: Harvard University Press: 191-211.

Hyder, D. N.; Sneva, F. A. 1956. Herbage response to sagebrush spraying. Journal of Range Management. 9: 34-38.

Johnson, K. L. 1979. Basic synecological relationships of the sagebrush types on the high plains of Montana, Wyoming, and the Dakotas. In: The sagebrush ecosystem: a symposium; Proceedings; 1979 April; Logan, UT. Logan, UT: Utah State University: 42-49.

Klebenow, D. A. 1972. The habitat requirements of sage grouse and the role of fire in management. In: Proceedings Tall Timbers Fire Ecology Conference No. 12; 1972 June 8-9; Lubbock, TX. Tallahassee, FL: Tall Timbers Research Station: 305-315.

Klebenow, D. A.; Beall, R. C. 1977. Fire impacts on birds and mammals on Great Basin Rangelands. In: Proceedings of the 1977 rangeland management and fire symposium; 1977 November 1-3; Casper, WY. Missoula, MT: University of Montana: 59-62.

Komarek, E. V. 1969. Fire and animal behavior. In: Proceedings Tall Timbers Fire Ecology Conference No. 9; 1969 April 10-11; Tallahassee, FL. Tallahassee, FL: Tall Timbers Research Station: 161-207.

Kramp, B. A.; Patton, D. R.; Brady, W. W. 1983. RUN WILD, wildlife/habitat relationships: the effects of fire on wildlife habitat and species. Wildlife Unit Tech. Rep. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 29 p.

Kuntz, D. E. 1982. Plant response following spring burning in an *Artemisia tridentata* subsp. *vaseyana/idahoensis* habitat type. Moscow, ID: University of Idaho. 73 p. M.S. thesis.

Lotan, J. E.; Alexander, M. E.; Arno, S. F.; [and others]. 1981. Effects of fire on flora: a state-of-the-knowledge review. Gen. Tech. Rep. WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service. 71 p.

Lowe, P. O.; Ffolliott, P. F.; Dietrick, J. H.; Patton, D. R. 1978. Determining potential wildlife benefits from wildfires in Arizona ponderosa pine forests. Gen. Tech. Rep. RM-52. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.

Lyon, L. J.; Stickney, P. F. 1976. Early vegetal succession following large northern Rocky Mountain wildfires. In: Proceedings Tall Timbers Fire Ecology Conference No. 14; 1974 October 8-10; Missoula, MT. Tallahassee, FL: Tall Timbers Research Station: 355-373.

Lyon, L. J.; Crawford, H. S.; Czuhai, E.; [and others]. 1978. Effect of fire on fauna: a state-of-the-knowledge review. Gen. Tech. Rep. WO-6. Washington, DC: U.S. Department of Agriculture, Forest Service. 22 p.

Martin, R. E.; Dell, J. D. 1978. Planning for prescribed fires in the Inland Northwest. Gen. Tech. Rep. PNW-76. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 67 p.

McArthur, E. D.; Blauer, A. C.; Plummer, A. P.; Stevens, R. 1979. Characteristics and hybridization of important Intermountain shrubs. III. Sunflower family. Res. Pap. INT-220. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 82 p.

McArthur, E. D.; Welch, B. L., compilers. 1986. Proceedings—symposium on the biology of *Artemisia* and *Chrysothamnus*. Gen. Tech. Rep. INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 398 p.

Miller, R. F.; Vavra, M. 1982. Deer, elk and cattle diets on northeastern Oregon rangelands. In: Wildlife-livestock relationships: Proceedings of a symposium; 1981; Couer d'Alene, ID. Moscow, ID: University of Idaho, Forestry, Wildlife, and Range Experiment Station: 500-508.

Monsen, S. B.; McArthur, E. D. 1985. Factors influencing establishment of seeded broadleaf herbs and shrubs following fire. In: Rangeland fire effects: a symposium; Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office: 112-124.

Morris, M. S.; Kelsey, R. C.; Griggs, D. 1976. Geographic and ecological distribution of big sagebrush and other woody *Artemisias* in Montana. Montana Academy of Sciences. 36: 56-79.

Mosley, J. C. 1983. Determining range condition from frequency data in mountain meadows of central Idaho. Moscow, ID: University of Idaho. 81 p. M.S. thesis.

Mueggler, W. F. 1976. Number of plots required for measuring productivity on mountain grasslands in Montana. Res. Note INT-207. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.

Mueggler, W. F.; Blaisdell, J. P. 1956. Effects on associated species of burning, rotobeating, spraying, and railing sagebrush. Journal of Range Management. 11: 61-66.

Mueggler, W. F.; Stewart, W. C. 1980. Grassland and shrubland habitat types of western Montana. Gen. Tech. Rep. INT-66. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 154 p.

Mueller-Dombois, D.; Ellenberg, H. 1974. Aims and methods of vegetation ecology. New York: J. Wiley and Sons. 547 p.

Neuenschwander, L. F. 1980. Broadcast burning of sagebrush in winter. Journal of Range Management. 33: 233-236.

Pechanec, J. F.; Plummer, A. P.; Robertson, J. H.; Hull, A. C. 1965. Sagebrush control on rangelands. Agric. Handb. 277. Washington, DC: U.S. Department of Agriculture, Forest Service. 40 p.

Pickford, G. D. 1932. The influence of continued heavy grazing and promiscuous burning on spring-fall ranges in Utah. Ecology. 13: 159-171.

Pieper, R. D. 1978. Measurement techniques for herbaceous and shrubby vegetation. Las Cruces, NM: New Mexico State University. 147 p. Mimeo.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 40 p.

Rothermel, R. C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden, UT: U.S. Department of Agriculture,

Forest Service, Intermountain Forest and Range Experiment Station. 161 p.
Schlatterer, E. F. 1972. A preliminary description of plant communities found on the Sawtooth, White Clouds, Boulder and Pioneer Mountains. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 73 p. Mimeo.
Schott, M. R. 1981. Classification and ordination of seral communities. Moscow, ID: University of Idaho. 154 p. M.S. thesis.
Schripsema, J. R. 1977. Ecological changes on pine-grassland burned in spring, late winter, and winter. Brookings, SD: South Dakota State University. 63 p. M.A. thesis.
Schroeder, M. J.; Buck, C. C. 1970. Fire weather. Agric. Handb. 360. Washington, DC: U.S. Department of Agriculture, Forest Service. 229 p.
Seip, D. R.; Bunnell, F. L. 1975. Nutrition of Stone's sheep on burned and unburned ranges. Journal of Wildlife Management. 49: 397-405.
Sheehy, P. P. 1975. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. Corvallis, OR: Oregon State University. 147 p. M.S. thesis.
Smith, S. D. 1982. Evaluation of the frequency plot method as an improved technique for measuring successional trend. Moscow, ID: University of Idaho. 95 p. M.S. thesis.
Smith, S. D.; Bunting, S. C.; Hironaka, M. 1986. Sensitivity of frequency plots for detecting vegetation change. Northwest Science. 60: 279-286.
Susott, R. A.; Burgan, R. E. 1986. Fire behavior computations with the Hewlett-Packard HP-71B calculator. Gen. Tech. Rep. INT-202. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 80 p.
Stoddart, L. A.; Smith, A. D.; Box, T. W. 1975. Range management. 3d ed. New York: McGraw-Hill. 532 p.
Tisdale, E. W.; Hironaka, M. 1981. The sagebrush-grass region: a review of the ecological literature. Bull. 33. Moscow, ID: University of Idaho, Forestry, Wildlife, and Range Experiment Station. 31 p.
Tisdale, E. W.; Hironaka, M.; Fosberg, F. A. 1969. The sagebrush region in Idaho: a problem in range resource management. Bull. 512. Moscow, ID: University of Idaho, Agricultural Experiment Station. 15 p.
Vallentine, J. F. 1971. Range developments and improvements. Provo, UT: Brigham Young University Press. 516 p.
West, N. E. 1979. Basic synecological relationships of shrub-dominated lands in the Great Basin and the Colorado Plateau. In: The sagebrush ecosystem: a symposium: Proceedings; 1979 April; Logan, UT. Logan, UT: Utah State University: 33-41.
White, R. S.; Currie, P. O. 1982. Prescribed burning in northern mixed grass plant communities. In: Society for Range Management abstracts, 35th annual meeting, Calgary, Alberta, Canada: 36.
Winward, A. H. 1970. Taxonomic and ecological relationships of the big sagebrush complex in Idaho. Moscow, ID: University of Idaho. 80 p. Ph.D. dissertation.
Winward, A. H.; Tisdale, E. W. 1977. Taxonomy of the *Artemisia tridentata* complex in Idaho. Bull. 19. Moscow, ID: University of Idaho, Forestry, Wildlife, and Range Experiment Station. 15 p.
Wright, H. A.; Klemmedson, J. O. 1965. Effects of fire on bunch-grasses of the sagebrush-grass region in southern Idaho. Ecology. 46: 680-688.
Wright, H. A.; Bailey, A. W. 1980. Fire ecology and prescribed burning in the Great Plains—a research review. Gen. Tech. Rep. INT-77. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 60 p.
Wright, H. A.; Bailey, A. W. 1982. Fire ecology: United States and southern Canada. New York: John Wiley and Sons. 501 p.
Wright, H. A.; Neuenschwander, L. F.; Britton, C. M. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: a state-of-the-art review. Gen. Tech. Rep. INT-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.
Zamora, B.; Tueller, P. T. 1973. *Artemisia arbuscula, A. longiloba* and *A. nova* habitat types in northern Nevada. Great Basin Naturalist. 33: 225-242.

APPENDIX A: LIST OF SPECIES (SCIENTIFIC AND COMMON NAMES) USED IN THE TEXT.

Scientific name	Common name
Trees and Shrubs	
Artemisia arbuscula	low sagebrush
Artemisia cana	silver sagebrush
Artemisia nova	black sagebrush
Artemisia rigida	stiff sagebrush
Artemisia tridentata	
ssp. *tridentata*	basin big sagebrush
ssp. *vaseyana*	mountain big sagebrush
ssp. *wyomingensis*	Wyoming big sagebrush
Artemisia tridentata	
ssp. *vaseyana* form *xericensis*	"species X"
Artemisia tripartita	threetip sagebrush
Chrysothamnus spp.	rabbitbrush
Juniperus spp.	juniper
Pinus ponderosa	ponderosa pine
Pseudotsuga menziesii	Douglas-fir
Purshia tridentata	antelope bitterbrush
Tetradymia canescens	gray horsebrush
Grasses	
Agropyron smithii	western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Bouteloua gracilis	bluegrama
Bromus tectorum	cheatgrass
Elymus (Taeniatherum)	
caput-medusae	medusahead
Elymus cinereus	Great Basin wildrye
Festuca idahoensis	Idaho fescue
Poa sandbergii	Sandberg bluegrass
Poa spp.	bluegrass
Sitanion hystrix	bottlebrush squirreltail
Stipa comata	needle-and-thread
Stipa thurberiana	Thurber's needlegrass

Nomenclature used follows that of Hitchcock and Cronquist (1973) except for that of *Artemisia* which follows Beetle (1960) and Winward and Tisdale (1977).

APPENDIX B: ANNOTATED BIBLIOGRAPHY OF SAGEBRUSH-FIRE LITERATURE

For literature published prior to 1980, see Wright and others (1979), Tisdale and Hironaka (1981), Harniss and others (1981), and Blaisdell and others (1982).

Albini, F. A. 1983. Potential spotting distance from wind-driven surface fires. Res. Pap. INT-309. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 27 p.
Fire behavior.

Anderson, H. E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.
Fuels.

Anderson, H. E. 1983. Predicting wind-driven wild land fire size and shape. Res. Pap. INT-305. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 26 p.
Fire behavior.

Astroth, K. A.; Frischknecht, N. C. 1984. Managing Intermountain rangelands—research on the Benmore Experimental Range, 1940-1984. Gen. Tech. Rep. INT-175. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 44 p.
Fire management, fire prescriptions, conifer invasion, succession, *Juniperus*, *Bromus*, forbs, *Agropyron desertorum*, *Agropyron spicatum*, *Agropyron smithii*, *Chrysothamnus*.

Blaisdell, J. P.; Murray, R. B.; McArthur, E. D. 1982. Managing Intermountain rangelands—sagebrush/grass ranges. Gen. Tech. Rep. INT-134. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 41 p.
Fire management, succession, plant productivity, soil-nutrients, soil general, planning, fire prescriptions, *Chrysothamnus*, *Tetradymia*, *Symphoricarpos*, *Prunus*, *Purshia*, *Artemisia tripartita*, *Artemisia cana*, *Artemisia tridentata vaseyana*, *Agropyron dasystachyum*, *Calamagrostis*, *Festuca*, *Poa*, *Stipa comata*, *Koeleria*, *Eriogonum*, *Antennaria*.

Britton, C. M.; Clark, R. G. 1985. Effects of fire on sagebrush and bitterbrush. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium: Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 22-26.
Fuels, *Purshia*.

Britton, C. M.; Clark, R. G.; Sneva, F. A. 1983. Effects of soil moisture on burned and clipped Idaho fescue. Journal of Range Management. 36: 708-710.
Soil-moisture, morphology, physiology, plant productivity, herbivory, *Festuca*.

Brown, J. C.; Evans, R. A.; Young, J. A. 1985. Effect of sagebrush control methods and seeding on runoff and erosion. Journal of Range Management. 38: 195-199.
Soil, erosion, watershed, *Artemisia tridentata wyomingensis*, *Agropyron desertorum*.

Brown, J. K. 1982. Fuel and fire behavior prediction in big sagebrush. Res. Pap. INT-290. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.
Fuels, fire behavior.

Brown, J. K.; Oberheu, R. D.; Johnston, C. M. 1982. Handbook for inventorying surface fuels and biomass in the Interior West. Gen. Tech. Rep. INT-129. Ogden, UT: U.S. Department of Agricuture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.
Fuels.

Bunting, S. C. 1985. Fire in sagebrush-grass ecosystems: successional changes. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium: Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 7-11.
Succession, resprouting, plant productivity, seedling establishment.

Bunting, S. C.; Neuenschwander, L. F.; Gruell, G. E. 1985. Fire ecology of antelope bitterbrush in the Northern Rocky Mountains. In: Lotan, J. E.; Brown, J. K., compilers. Fire's effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 48-57.

Succession, fire management, resprouting, seedling establishment, *Purshia.*

Bushey, C. L. 1985. Comparison of observed and predicted fire behavior in the sagebrush/bunchgrass vegetation type. In: Long, J. N., ed. Fire management: the challenge of protection and use; Proceedings; 1985 April 17-19; Logan, UT. Logan, UT: Utah State University: 187-191.

Fire behavior, fuels, fire management.

Chase, C. H. 1984. Spotting distance from wind-driven surface fires—extensions of equations for pocket calculators. Res. Note INT-346. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 21 p.

Fire behavior.

Clark, R. G.; Britton, C. M.; Sneva, F. A. 1982. Mortality of bitterbrush after burning and clipping in eastern Oregon. Journal of Range Management. 35: 711-714.

Herbivory, mortality, resprouting, soil-moisture, severity, plant productivity, morphology, *Purshia.*

Cluff, G. J.; Young, J. A.; Evans, R. A. 1983. Edaphic factors influencing the control of Wyoming big sagebrush and seedling establishment of crested wheatgrass. Journal of Range Management. 36: 786-792.

Seedling establishment, soil-moisture, soil, mortality, resprouting, *Artemisia tridentata vaseyana, Agropyron cristatum, Chrysothamnus.*

Crane, M. F.; Fischer, W. C. 1986. Fire ecology of central Idaho forest habitat types. Gen. Tech. Rep. INT-218. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 86 p.

Succession, conifer invasion, fire frequency, fire management, fuels, *Pinus, Pseudotsuga, Populus, Amelanchier, Ceanothus, Cercocarpus ledifolius, Prunus, Purshia,* shrubs, *Achillea,* forbs, *Balsamorhiza, Agropyron spicatum, Festuca, Koeleria.*

Davis, K. M.; Clayton, B. D.; Fischer, W. C. 1980. Fire ecology of Lolo National Forest habitat types. Gen. Tech. Rep. INT-79. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 77 p.

Succession, conifer invasion, fire frequency, fire management, fuels, *Juniperus, Pinus, Pseudotsuga, Ceanothus, Symphoricarpos, Purshia.*

Dealy, V. E.; Leckenby, D. A.; Concannon, D. M. 1981. Wildlife habitats in managed rangelands—the Great Basin of southeastern Oregon: plant communities and their importance to wildlife. Gen. Tech. Rep. PNW-120. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 120 p.

Fire management, wildlife-general.

Dean, S.; Burkhardt, J. W.; Meeuwig, R. O. 1981. Estimating twig and foliage biomass of sagebrush, bitterbrush, and rabbitbrush in the Great Basin. Journal of Range Management. 34: 224-227.

Fuels, morphology, *Artemisia tridentata tridentata, Artemisia tridentata vaseyana, Artemisia tridentata wyomingensis, Artemisia arbuscula, Artemisia nova, Purshia, Chrysothamnus.*

Driver, C. H. 1983. Potentials for the management of bitterbrush habitats by the use of prescribed fire. In: Tiedemann, A. R.; Johnson, K. L., compilers. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 137-141.

Resprouting, seedling establishment, fire management, *Purshia.*

Evans, R. A.; Young, J. A. 1983. Dynamics of antelope bitterbrush seed caches. In: Tiedemann, A. R.; Johnson, K. L. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 195-202.

Fire management, seedling establishment, *Purshia.*

Everett, R. L.; Sharrow, S. H. 1983. Responses of understory species to tree harvesting and fire in pinyon-juniper woodlands. In: Monsen, S. B.; Shaw, N., compilers. Managing Intermountain rangelands—improvement of range and wildlife habitats; Proceedings of symposia; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 62-66.

Succession, *Juniperus.*

Frandsen, O. A. 1985. Fire as a management tool in southwest Idaho—a case study. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium: Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 85-87.

Fire management.

Frandsen, W. H. 1983. Modeling big sagebrush as fuel. Journal of Range Management. 36: 596-600.

Fire behavior, fuels, morphology, *Artemisia tridentata wyomingensis, Artemisia tridentata tridentata.*

Gruell, G. E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume I —photographic record and analysis. Res. Pap. INT-235. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 207 p.

Succession, conifer invasion, wildlife-general.

Gruell, G. E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume II —changes and causes, management implications. Res.

Pap. INT-252. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 35 p.
Succession, conifer invasion, wildlife-general, *Pinus, Pseudotsuga, Populus, Salix, Artemisia tridentata vaseyana.*

Gruell, G. E. 1983. Fire and vegetative trends in the Northern Rockies: interpretations from 1871-1982 photographs. Gen. Tech. Rep. INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 117 p.
Succession, conifer invasion, fire frequency, wildlife-general.

Gruell, G. E. 1985. Fire on the early western landscape: an annotated record of wildland fires 1776-1900. Northwest Science. 59: 97-107.
Fire frequency, fire history.

Gruell, G. E. 1986. Post-1900 mule deer irruptions in the Intermountain West. Gen. Tech. Rep. INT-206. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 37 p.
Wildlife-deer.

Gruell, G. E.; Brown, J. K.; Bushey, C. L. 1986. Prescribed fire opportunities in grasslands invaded by Douglas-fir: state-of-the-art guidelines. Gen. Tech. Rep. INT-198. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 19 p.
Succession, conifer invasion, wildlife effects, fire frequency, fire history, plant productivity, *Juniperus, Populus, Pseudotsuga, Artemisia tridentata vaseyana, Cercocarpus ledifolius, Chrysothamnus, Prunus, Agropyron spicatum, Festuca, Stipa richardsonii, Koeleria.*

Gruell, G.; Bunting, S.; Neuenschwander, L. 1985. Influence of fire on curlleaf mountain-mahogany in the Intermountain West. In: Lotan, J. E.; Brown, J. K., compilers. Fire's effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 58-72.
Fire history, fire management, resprouting, seedling establishment, succession, *Cercocarpus ledifolius.*

Johansen, J. R.; Javakul, A.; Rushforth, S. R. 1982. Effects of burning on the algal communities of a high desert soil near Wallsburg, Utah. Journal of Range Management. 35: 598-600.
Soil, soil-erosion, *Amelanchier.*

Johnson, A. H.; Strang, R. M. 1983. Burning in a bunchgrass/sagebrush community: the southern interior of B.C. and northwestern U.S. compared. Journal of Range Management. 36: 616-617.
Mortality, seedling establishment, resprouting, plant productivity.

Keeley, J. E. 1981. Reproductive cycles and fire regimes. In: Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 231-277.
Succession, conifer invasion, fire frequency, *Sporobolus, Ceanothus, Pinus, Pseudotsuga, Juniperus, Populus.*

Kilgore, B. M. 1981. Fire in ecosystem distribution and structure: western forests and shrublands. In: Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 58-89.
Fire frequency, fire management, *Bromus.*

Kindschy, R. R.; Sundstrom, C.; Yoakum, J. D. 1982. Wildlife habitats in managed rangelands—the Great Basin of southeastern Oregon. Gen. Tech. Rep. PNW-145. Portland, OR: U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station. 18 p.
Wildlife-pronghorn, fire management.

Klebenow, D. A. 1985. Big game response to fire in sagebrush-grass rangelands. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 53-57.
Succession, wildlife-big horn, deer, elk, pronghorn.

Kramp, B. A.; Patton, D. R.; Braoy, W. W. 1983. The effects of fire on wildlife habitat and species. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region; Wildlife Unit Tech. Rep. 29 p.
Fire management, morphology, physiology, wildlife-general.

Lotan, J. E.; Alexander, Martin E.; Arno, Stephen F.; [and others]. 1981. Effects of fire on flora: a state-of-knowledge review. Gen. Tech. Rep. WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service. 71 p.
Fire frequency, *Juniperus, Festuca, Stipa comata, Populus, Pinus, Pseudotsuga.*

Mangan, L.; Autenrieth, R. 1985. Vegetation changes following 2,4-D application and fire in a mountain big sagebrush habitat type. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium: Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 61-65.
Wildlife, *Lupinus, Epilobium, Agoseris.*

Martin, R. E.; Driver, C. H. 1983. Factors affecting antelope bitterbrush restablishment following fire. In: Tiedemann, A. R.; Johnson, K. L., compilers. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 266-279.
Resprouting, morphology, physiology, mortality, succession, herbivory, fuel, seedling establishment, fire management, *Purshia, Pinus, Juniperus, Bromus.*

Martin, R. E.; Frewing, D. W.; McClanahan, J. L. 1981. Average biomass of four Northwest shrubs by the fuel size class and crown cover. Res. Note PNW-374. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 6 p.
Fuels, *Purshia, Ceanothus.*

Martin, R. E.; Olson, C. M.; Sleznick, J., Jr. 1982. Research/management prescribed burning at Lava Beds National Monument. In: Ecological research in national parks of the Pacific Northwest. Forest Research Laboratory Publication. Corvallis, OR: Oregon State University: 83-91.
Fire prescriptions, fire management, fuels, *Cercocarpus, Pinus, Purshia, Bromus tectorum, Sitanion, Chrysothamnus, Festuca, Elymus, Poa.*

Marty, R. J.; Barney, R. J. 1981. Fire costs, losses, and benefits: an ecomomic valuation procedure. Gen. Tech. Rep. INT-108. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p.
Economics.

McGee, J. M. 1982. Small mammal populations in an unburned and early fire successional sagebrush community. Journal of Range Management. 35: 177-180.
Wildlife-rodents, nongame, succession, *Artemisia tridentata vaseyana, Agropyron, Festuca, Poa, Stipa.*

Monsen, S. B.; McArthur, E. D. 1985. Factors influencing establishment of seeded broadleaf herbs and shrubs following fire. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium: Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 112-124.
Seedling establishment, rehabilitation.

Murray, R. B. 1983. Response of antelope bitterbrush to burning and spraying in southeastern Idaho. In: Tiedemann, A. R.; Johnson, K. L., compilers. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 142-152.
Fire management, plant productivity, resprouting, seedling establishment, mortality, succession, *Purshia, Artemisia tridentata vaseyana, Chrysothamnus, Tetradymia.*

Neuenschwander, L. F. 1980. Broadcast burning of sagebrush in winter. Journal of Range Management. 33: 233-235.
Fire behavior, planning, fire prescriptions.

Noste, N. V. 1985. Influence of fire severity on response of evergreen ceanothus. In: Lotan, J. E.; Brown, J. K., compilers. Fire's effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 91-96.
Fire management, severity, succession, morphology, *Ceanothus.*

Noste, N. V.; Bushey, C. L. [In press]. Fire effects on dry habitats in Montana and Idaho. Gen. Tech. Rep. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.
Resprouting, fire management, fire severity, seed production, physiology, morphology, *Arctostaphylos, Symphoricarpos, Spirea, Amelanchier, Juniperus, Prunus, Purshia,* shrubs, forbs.

Olsen, C. M.; Johnson, A. H.; Martin, R. E. 1982. Effects of prescribed fires on vegetation in Lava Beds National Monument. In: Ecological research in national parks of the Pacific Northwest. Forest Research Laboratory Publication. Corvallis, OR: Oregon State University: 92-100.
Fire management, resprouting, physiology, *Pinus, Juniperus, Cercocarpus ledifolius, Purshia, Ribes,* forbs, *Stipa thurberiana, Sitanion, Eriogonum, Agropyron spicatum, Stipa occidentalis, Carex, Festuca, Poa, Chrysothamnus, Stipa comata, Tetradymia, Bromus tectorum, Elymus.*

Peek, J. M.; Demarchi, D. A.; Demarchi, R. A.; Stucker, D. E. 1985. Bighorn sheep and fire: seven case histories. In: Lotan, J. E.; Brown, J. K., compilers. Fire's effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. Gen. Tech. Rep. INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 36-43.
Wildlife-bighorn sheep, fire management, succession, conifer invasion, fire history, resprouting, seedling establishment, *Purshia, Pseudotsuga, Artemisia frigida, Agropyron spicatum, Stipa comata, Festuca, Poa, Calamagrostis, Bromus, Cercocarpus ledifolius, Artemisia tridentata wyomingensis.*

Purcell, A.; Schnoes, R.; Starkey, E. 1982. The effects of prescribed burning on mule deer in Lava Beds National Monument. In: Ecological research in national parks of the Pacific Northwest. Forest Research Laboratory Publication. Corvallis, OR: Oregon State University: 111-120.
Fire management, wildlife-deer.

Range, P.; Veisze, P.; Beyer, C.; Zschaechner, G. 1982. Great Basin rate-of-spray study. Reno, NV: U.S. Department of the Interior, Bureau of Land Management, Nevada State Office. 56 p.
Fire behavior, fire prescriptions, fuels, monitoring, planning, resprouting, *Chrysothamnus, Symphoricarpos, Purshia, Agropyron spicatum, Festuca, Poa, Sitanion, Stipa columbiana, Elymus, Bromus,* forbs, *Opuntia, Balsamorhiza, Lupinus, Collinsia.*

Raper, B.; Clark, B.; Matthews, M.; Aldrich, A. 1985. Early effects of a fall burn in a western Wyoming mountain big sagebrush-grass community. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium: Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 88-92.
Plant production.

Rice, C. L. 1983. A literature review of the fire relationships of antelope bitterbrush. In: Tiedemann, A. R.; Johnson, K. L., compilers. Proceedings—research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 256-265.
Fire frequency, fuels, resprouting, seedling establishment, fire management, physiology, *Prunus, Pinus, Juniperus, Tetradymia, Chrysothamnus.*

Rickard, W. H.; McShane, M. C. 1984. Demise of spiny hopsage shrubs following summer wildfire: an authentic

record. Northwest Science. 58: 282-285.
Wildfire, *Sarcobatus, Grayia, Atriplex.*

Rothermel, R. C. 1983. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 161 p.
Fuels, fire behavior.

Rothermel, R. C.; Deeming, J. E. 1980. Measuring and interpreting fire behavior for correlation with fire effects. Gen. Tech. Rep. INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
Fire behavior.

Rothermel, R. C.; Rhinehart, G. C. 1983. Field procedures for verification and adjustment of fire behavior predictions. Gen. Tech. Rep. INT-142. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 25 p.
Fire behavior, monitoring.

Rundel, P. W. 1981. Structural and chemical components of flammability. In: Fire regimes and ecosystem properties: Proceedings of the conference; 1978 December 11-15; Honolulu, HI. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 183-207.
Physiology, morphology, *Pseudotsuga, Pinus, Populus, Ceanothus.*

Smith, M. A.; Busby, F. 1981. Prescribed burning: effective control of sagebrush in Wyoming. Research Journal 165. Laramie, WY: University of Wyoming, Agriculture Experiment Station.
Fire management, planning.

Smith, M. A.; Dodd, J. L.; Rodgers, J. D. 1985. Prescribed burning on Wyoming rangeland. Bulletin B-810. Laramie, WY: University of Wyoming, Agriculture Extension Service. 25 p.
Plant production, herbivory, planning, fire prescriptions, *Sarcobatus, Symphoricarpos, Amelanchier, Agropyron smithii, Agropyron dasystachyum, Bouteloua gracilis.*

Tiagwad, T. E.; Olsen, C. M.; Martin, R. E. 1982. Single-year response of breeding bird populations to fire in a curlleaf mountain mahogany—big sagebrush community. In: Ecological research in national parks of the Pacific Northwest. Forest Research Laboratory Publication. Corvallis, OR: Oregon State University: 101-110.
Fire management, wildlife-nongame.

Uresk, D. W.; Rickard, W. H.; Cline, J. F. 1980. Perennial grasses and their response to a wildfire in south-central Washington. Journal of Range Management. 33: 111-114.
Plant productivity, morphology, physiology, *Poa, Agropyron spicatum, Stipa thurberiana.*

Volland, L. A.; Dell, J. D. 1981. Fire effects on Pacific Northwest forest and range vegetation. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; Rm 067. 23 p.
Morphology, physiology, plant productivity, fire frequency, *Pseudotsuga, Pinus, Populus, Purshia, Agropyron trachycaulum, Agropyron spicatum, Agropyron cristata, Sitanion, Bromus, Festuca, Poa, Stipa comata, Stipa columbiana, Koeleria, Prunus, Symphoricarpos, Cercocarpus ledifolius, Chrysothamnus, Tetradymia, Rosa, Salix, Amplanichia, Ceanothus, Balsamorhiza, Arnica, Antennaria, Zigadenus, Castilleja, Senecio, Lupinus, Calochortus, Rumex, Fragaria, Cirsium, Achillea, Allium, Eriogonum.*

Wagstaff, F. J. 1983. Evaluating proposed improvements of public rangelands. Gen. Tech. Rep. INT-150. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
Economics.

West, N. E.; Hassan, M. A. 1985. Recovery of sagebrush-grass vegetation following wildfire. Journal of Range Management. 38: 131-134.
Plant production, *Artemisia tridentata wyomingensis, Chrysothamnus, Ephedra, Artemisia nova, Agropyron spicatum, Agropyron smithii, Stipa comata, Poa, Sitanion, Bromus, Oryzopsis, Erigeron, Phlox.*

Whisenant, S. G. 1985. A multidisciplinary approach to evaluating fire effects. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium; Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 98-104.
Monitoring, succession.

White, R. S.; Currie, P. O. 1983. The effects of prescribed burning on silver sagebrush. Journal of Range Management. 36: 611-613.
Mortality, monitoring, resprouting, fuels, severity, *Artemisia cana.*

Wikeem, B. M.; Strang, R. M. 1983. Prescribed burning on B.C. rangelands: the state of the art. Journal of Range Management. 36: 3-8.
Fire history, species diversity.

Willms, W.; Bailey, A. W.; McLean, A. 1980. Some effects of soil and air temperature on growth of *Agropyron spicatum* following clipping and burning. Canadian Journal of Botany. 58: 568-573.
Herbivory, plant production, soil.

Willms, W.; Bailey, A. W.; McLean, A. 1980. Effects of clipping or burning on some morphological characteristics of *Agropyron spicatum.* Canadian Journal of Botany. 58: 2309-2312.
Herbivory, plant production, soil-temperature, morphology.

Willms, W.; Bailey, A. W.; Mclean, A.; Kalnin, C. 1981. Effects of fall clipping or burning on the distribution of chemical constituents in bluebunch wheatgrass in spring. Journal of Range Management. 34: 267-269.
Physiology, soil-nutrients, *Agropyron spicatum.*

Willms, W.; Bailey, A. W.; McLean, A.; Tucker, R. 1980. The effects of fall grazing or burning bluebunch wheatgrass range on forage selection by deer and cattle in spring. Canadian Journal of Animal Science. 60: 113-122.
Wildlife-deer, plant productivity, herbivory, monitoring, *Pseudotsuga, Agropyron spicatum, Poa, Stipa comata, Lomatium, Erigeron, Tragopogon.*

Winward, A. H. 1985. Fire in the sagebrush-grass ecosystem—the ecological setting. In: Sanders, K.;

Durham, J.; [and others], eds. Rangeland fire effects: a symposium; Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 2-6.
Monitoring, fire management, *Chrysothamnus.*

Wright, H. A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium; Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 12-21.
Fire history, plant productivity, *Agropyron spicatum, Festuca, Carex, Poa, Bromus, Oryzopsis, Stipa, Koeleria, Sitanion.*

Wright, H. A.; Bailey, A. W. 1980. Fire ecology and prescribed burning in the Great Plains—a research review. Gen. Tech. Rep. INT-77. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 61 p.
Fire management, fire prescriptions, planning, smoke management, *Artemisia cana, Symphoricarpos, Festuca, Agropyron smithii, Agropyron dasystachyum, Agropyron spicatum, Koeleria, Stipa columbiana, Stipa comata, Achillea, Astragalus, Geum, Aster.*

Yoakum, J. 1983. Managing vegetation for pronghorns in the Great Basin. In: Monsen, S. B.; Shaw, N., compilers. Managing Intermountain rangelands—improvement of range and wildlife habitats; Proceedings of symposia; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 189-194.
Wildlife-pronghorn.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the Intermountain region. In: Managing Intermountain rangelands—improvement of range and wildlife habitats: Proceedings of symposia; 1981 September 15-17; Twin Falls, ID; 1982 June 22-24; Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 18-31.
Succession, fire management, planning, fire prescriptions, soil-general, *Purshia, Chrysothamnus, Artemisia nova, Artemisia cana, Artemisia tripartita, Artemisia arbuscula, Symphoricarpos, Cercocarpus ledifolius, Cercocarpus montanus, Prunus, Amelanchier, Ceanothus, Poa, Bromus, Festuca, Oryzopsis, Koeleria, Stipa columbiana, Stipa comata, Stipa occidentalis, Stipa thurberiana, Sitanion, Agropyron spicatum, Agropyron cristatum, Agropyron dasystachyum, Agropyron smithii, Agropyron intermedium, Phlox, Erigeron, Eriogonum, Antennaria, Astragalus, Penstemon, Descurainia, Geranium, Lupinus, Crepis, Cirsium, Balsamorhiza, Achillea, Allium, Chenopodium, Senecio, Zygadenus, Draba.*

Zschaechner, G. A. 1985. Studying rangeland fire effects: a case study in Nevada. In: Sanders, K.; Durham, J.; [and others], eds. Rangeland fire effects: a symposium; Proceedings; 1984 November 27-29; Boise, ID. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 66-84.
Monitoring, fire behavior, fire prescriptions, *Purshia, Chrysothamnus, Symphoricarpos, Amelanchier, Elymus.*

Bunting, Stephen C.; Kilgore, Bruce M.; Bushey, Charles L. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. Gen. Tech. Rep. INT-231. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 33 p.

Summarizes recent literature on the effects of fire on sagebrush-grass vegetation. Also outlines procedures and considerations for planning and conducting prescribed fires and monitoring effects. Includes a comprehensive annotated bibliography of the fire-sagebrush-grass literature published since 1980.

KEYWORDS: vegetation monitoring, prescribed fire, management planning, fire effects

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

Forest Service

Intermountain Research Station

General Technical Report INT-232

Western White Pine: An Annotated Bibliography

THE COMPILERS:

RAY J. HOFF is project leader for the Genetics and Pest Resistance of Rocky Mountain Conifers research work unit located at Intermountain Research Station's Forestry Sciences Laboratory, Moscow, ID. He has a B.A. in biology from Western Washington State University and a Ph.D. in botany from Washington State University.

JANET I. QUALLS is editorial assistant for Intermountain Research Station, Ogden, UT.

DALE O. COFFEN is forestry technician for the Genetics and Pest Resistance of Rocky Mountain Conifers research work unit located at Intermountain Research Station's Forestry Sciences Laboratory, Moscow, ID.

CONTENTS

October 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

Western White Pine: An Annotated Bibliography

Compilers

Ray J. Hoff
Janet I. Qualls
Dale O. Coffen

NTRODUCTION

This bibliography on western white pine (*Pinus onticola* Dougl.) contains references through 1984. rticles are listed by authors in alphabetical order, and all eferences have been abstracted. An author index and a ubject index are included. The subject index is based on he keywords for each citation. Numbers in the author and ubject indexes refer to entries in the bibliography.

The bibliography has been limited largely to articles in nglish, although a few foreign publications have been ncluded. References include both popular and scientific ublications. They also include unpublished theses and ypewritten reports. References dealing with white pine lister rust have been omitted unless they provide other ata or information.

IBLIOGRAPHY

AUTH Acosta, R. S.
DATE 1962
TITL Resultados obtenidos con plantaciones forestales en la zona montanosa de San Martin de los Andes-Neuquen.
PUBL In: Fifth World Forestry Congress; Seattle, WA; 1960; vol 2, sec 2: 768-772.
ABST The growth of 14 species of trees native to the United States in plantations in the area of San Martin de los Andes in the province of Neuquen is reported. A study of these plantations reveals environmental factor regimes favorable for these species. Also identified are nine adverse factors that hinder forestry in the Patagonia area.
KEYW Plantations, regional environmental factors.

AUTH Allen, J. W.
DATE 1959
TITL White pine in western Washington.
PUBL Journal of Forestry. 57: 573-576.
ABST The following figures were given for western white pine in western Washington: annual cut, low 2.8 thousand bd ft in 1949, high 8.7 thousand bd ft in 1941, mean 1940-1956, 6.0 thousand bd ft; total merchantable volume, range 0.1 percent to 4.0 percent, average 0.4 percent (1957 figures); distribution was characterized as scattered throughout area; growth rate, no information available; value, \$15 to \$30 per thousand bd ft for mature white pine. It was noted that the annual cut was low enough to maintain the species, but that rapid deterioration from blister rust and beetles indicated the need for a major effort to salvage as much volume as possible.
KEYW Annual cut, merchantable volume, distribution, value, western Washington.

3 AUTH Allison, F. E., Murphy, R. M.
DATE 1963
TITL Comparative rates of decomposition in soil of wood and bark particles of several species of pines.
PUBL Soil Science Society of America Proceedings. 63: 309-312.
ABST The finely ground wood and bark of nine species of pine including western white were allowed to decompose in soils in the presence and absence of additional nitrogen for periods of 63 to 800 days. Carbon dioxide evolution was measured at frequent intervals. An average of 16.2 percent of the wood carbon was oxidized in 60 days in the absence of extra nitrogen and 16.9 percent in its presence. Corresponding values for the bark were 8.7 and 8.6 percent. The wood species showed variation in CO_2 evolution during the 60-day period, ranging from 8 percent for sugar pine to 51 percent for shortleaf pine. The variation for the bark was between 3.0 percent for white pine and 23.3 percent for lodgepole pine. Most of the pine wood decomposed somewhat more rapidly than did the other softwoods previously studied, but not nearly so rapidly as did the hardwoods. Pine barks are oxidized at about the same slow rate as other softwood barks.
KEYW Decomposition, soils, wood particles, bark particles.

4 AUTH Amerson, H. V., Mott, R. L.
DATE 1982
TITL Improved rooting of western white pine shoots from tissue cultures.

PUBL Forest Science. 38(4): 822-825.
ABST Rooting of adventitious shoots of western white pine continuously exposed to a variety of growth regulators for 6 weeks varied between 0 and 20 percent. Pulse treatment of similar shoots for 7 days with the same growth regulator treatments followed by 5-week culture on medium devoid of growth regulators provided 40 to 64 percent rooting. In paired comparisons, pulse treatments always provided better rooting percentages than did constant exposure treatments. Improved root growth and the initiation of multiple roots were also favored by pulse treatments.
KEYW Tissue cultures, root initiation and growth.

5 AUTH Amman, G. D.
DATE 1982
TITL Characteristics of mountain pine beetles reared in four pine hosts.
PUBL Environmental Entomologist. 11(3): 590-593.
ABST Mountain pine beetles obtained from naturally infested lodgepole pine were reared in four common hosts: ponderosa pine, western white pine, whitebark pine, and lodgepole pine. Emerging beetles were collected daily, counted and sexed, and pronotal width was measured. Significant differences in brood production, size of female beetles, and developmental rate, but not sex ratio, occurred among hosts. Differences were not all associated with the same species of tree. However, the results indicate that, overall, lodgepole pine is the poorest and ponderosa pine is the best of the four hosts for mountain pine beetle.
KEYW Mountain pine beetle.

6 AUTH Anderson, A. B.
DATE 1944
TITL Chemistry of western pines.
PUBL Industrial and Engineering Chemistry. 36: 662-663.
ABST This article deals with the possible recovery and utilization of chemical products from three western pines. The newer methods of wood analysis, which were developed on other woods, are applicable to these important commercial woods. The extractives are not an integral part of the lumber, and because the pines are rich in this wood fraction, they offer an opportunity for economic recovery.
KEYW Wood analysis, extractives, economic recovery.

7 AUTH Anderson, A. B.
DATE 1950
TITL Chemistry of western white pines.
PUBL Industrial and Engineering Chemistry. 42(3): 565-569.
ABST This paper deals with the isolation and preliminary examination of the chemical nature of the extractives present in pine knots from three commercially important western pines—ponderosa, Idaho white, and sugar. Experimental evidence is offered for the first time, indicating which components in knot extract are largely responsible for paint discoloration over knots. The information was helpful in arriving at a knot-sealer formulation that has proved beneficial in alleviating this paint problem.
KEYW Knot extract, paint discoloration, knot sealer.

8 AUTH Anderson, A. B., Riffer, R. B., Wong, A.
DATE 1969
TITL Monoterpenes, fatty and resin acids of *Pinus lambertiana* and *Pinus monticola*.
PUBL Phytochemistry. 8: 869-872.
ABST The sapwood and heartwood of sugar pine and western white pine have been examined for monoterpenes and fatty and resin acids. The principal qualitative differences between the terpene compositions are the presence of delta (super 3)-carene in significant amounts in sugar pine and its apparent absence in western white pine, and the presence of n-decane in western white pine and its absence in sugar pine. The seldom-reported trans-cinnamic acid was found in each of these pines, but the recently reported sugar pine resin acid, lambertianic, was not found in western white pine.
KEYW Monoterpenes, fatty acids, resin acids.

9 AUTH Anderson, H. W., Wilson, B. C.
DATE 1966
TITL Improved stratification procedures for western white pine seed.
PUBL [Olympia, WA]: State of Washington, Department of Natural Resources; Report 8. 11 p.
ABST Two lots of coastal Washington western white pine seed were subjected to various combinations of warm (approximately 24 °C) and cold (2-5 °C) stratification and incubated for 30 days at 25 °C without light. Results were analyzed by analysis of variance. Warm stratification increased germination from 15.1 percent at no stratification to 33.2 percent at 30 days stratification. Cold stratification generally increased germination with increased length of stratification. The combination of 30 days cold stratification preceded by 30 days warm stratification significantly increased germination over all other treatments and almost doubled germination (56.8 percent versus 31.5 percent) when compared to the

recommended 90-day cold stratification period.
KEYW Seed stratification.

10 AUTH Anderson, I. V.
DATE 1930
TITL Log damage on gravity chutes: an analysis of volume and value loss of Idaho white pine logs.
PUBL The Timberman. 30(3): 1-4.
ABST The shorter logs in this study not only suffered the greatest value loss, but also lost the greatest volume per thousand feet of logs handled. Loss in lumber-selling value for this run (8.1 per thousand) of logs was $1.37 per thousand, but increased to $2.37 for logs running 14 logs per thousand. This represents the maximum loss to be expected where the average effort is made to check the logs and the usual trimming allowance of 6 to 8 inches is used. The volume-loss log scale from chute defects in this study can be considered as 4 percent for timber running eight and nine logs to the thousand, 5 percent for 10-, 11-, and 12-log timber, and 6 percent for 13- and 14-log timber. These figures are only applicable to steep chute chances where the average precautions are taken to reduce log damage. A maximum trimming allowance of 10 inches is necessary to avoid excessive brooming and splitting loss on all chutes too steep for trailing. Well-constructed and properly located "bear traps" will no doubt eliminate this loss and, where they work, are more desirable than using the extra trimming allowance. Slabbing defect is not serious unless the "goose necks" are set to whirl the logs, thereby scoring the entire outside perimeter of the log.
KEYW Log damage.

11 AUTH Anderson, I. V.
DATE 1932
TITL Breakage in felling study: western white pine type.
PUBL Unpublished report. On file at : U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID. 3 p.
ABST The tables and explanatory notes in this memorandum have been prepared only as an office record for the breakage study of the western white pine type. Compilations are given for variations in direction of felling and slope; frozen and unfrozen timber felled on bare ground and in different depths of snow; by causes (windfall, log, stump, rock, and miscellaneous); by character of ground; by number of lots per tree classes; and by age class segregation.
KEYW Felling breakage.

12 AUTH Anderson, I. V.
DATE 1932
TITL Office memoranda on methods of procedure and results of the Ohio Match Company project.
PUBL Unpublished report. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID. 44 p.
ABST These memoranda describe in detail the procedures used in conducting a study of an Ohio Match Company gyppo logging project. Data includes description of the area, logging methods, objectives and techniques, early results of the study, and the reason for termination. They also include a comparison of logging and milling costs to lumber selling values by tree sizes, stand tables of the area, and stand and volume data.
KEYW Gyppo logging, logging.

13 AUTH Anderson, I. V.
DATE 1934
TITL Breakage losses and cull percent of timber in the Inland Empire.
PUBL Applied Forest Note 63. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Cull percentage for western white pine averaged 15 percent, ranging from 3 percent in trees 80 to 100 years old to 24 percent in trees over 300 years old.
KEYW Breakage loss, cull percentage.

14 AUTH Anderson, I. V.
DATE 1935
TITL Match plank and commercial lumber from western white pine logs.
PUBL Applied Forestry Note 72. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Out of the 356 million feet of western white pine produced in 1934 in the Inland Empire, a total of 101 million feet was match plank. This constituted 28 percent of the total cut.
KEYW Matches, lumber, match plank.

15 AUTH Anderson, I. V.
DATE 1939
TITL Review of "Results and application of a logging and milling study in western white pine of northern Idaho," by E. F. Rapraeger.
PUBL Journal of Forestry. 37: 505.
ABST Anderson concludes, "The bulletin is well worth careful study by students and practicing foresters interested in the economics of logging and milling."
KEYW Logging, milling, economics.

16 AUTH Anderson, I. V.
DATE 1948
TITL Specifications for knotty western white pine veneer flitches.
PUBL Research Note 68. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 1 p.
ABST Specifications are given for knotty western white pine flitches. Logs yielding satisfactory slicing flitches are usually from the limby portion of the tree where knots are small, sound, and properly spaced. Logs cutting a high proportion of No. 2 common lumber give highest flitch yields.
KEYW Knotty flitches.

17 AUTH Anderson, I. V.
DATE 1954
TITL Suitability of Rocky Mountain woods for veneer and plywood.
PUBL Journal of Forestry. 52(8): 587-591.
ABST Current and future trends in utilization of Rocky Mountain tree species for veneer and plywood production are discussed. The highest potential for commercial expansion is foreseen to be in the field of knotty paneling.
KEYW Veneer, plywood, knotty paneling.

18 AUTH Andresen, J. W.
DATE 1966
TITL A multivariate analysis of the *Pinus chiapensis-monticola-strobus* phylad.
PUBL Rhodora. 68(773): 1-24.
ABST Provides a statistical basis for a determination of the proper taxonomic disposition of this controversial taxon. A companion paper (Andreson 1964) recommends that *P. strobus* var. *chiapensis* be elevated from varietal to specific rank. This proposal was predicated on evidence from this study of morphologic and progeny data.
KEYW Taxonomy, multivariate analysis, coefficient of divergence, leaf characters, seedling characteristics.

19 AUTH Andrews, D. S.
DATE 1980
TITL Rooting western white pine, *Pinus monticola* Dougl., needle fascicles and branch cuttings.
PUBL Research Note INT-291. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p.
ABST Three experiments were conducted to investigate effects of IBA, kinetin, GA3, b-nine, sucrose, and of an acid and a base on the rooting of western white pine needle fascicles and branch cuttings. IBA, b-nine, sucrose, and acid were all effective in enhancing root initiation.
KEYW Vegetative propagation, rooting, rooting needle fascicles.

20 AUTH Arkwright, P.
DATE 1967
TITL Canadian white pines.
PUBL Woodwork Industry. 24: 37.
ABST Western white pine is used for much the same purposes as the eastern variety. It is a slightly heavier species, averaging 26 lb to the cubic foot air dry, but it is not suited for purposes where strength is of importance. The two varieties are very similar in general appearance, though the western white pine is normally rather darker in color in the heartwood and has a more noticeable growth ring figure. Although durability standards are (for a softwood) good without being really exceptional, western white pine is generally regarded as being less durable than the eastern variety.
KEYW Physical properties, uses.

21 AUTH Arno, S. F., Pfister, R. D.
DATE 1977
TITL Habitat types: an improved system for classifying Montana's forests.
PUBL Western Wildlands. 3: 6-11.
ABST The habitat types of Montana are described. Potential yield, watershed, recreation, and forest protection aspects are discussed.
KEYW Habitat types.

22 AUTH Arnold, D. L.
DATE 1948
TITL Growing space ratio as related to form and development of western white pine.
PUBL Moscow, ID: University of Idaho. 48 p. M.S. thesis.
ABST To gain an understanding of growing space relationships in normal stands of western white pine, average stand diameter and crown spread (spacing) for various ages and site qualities were calculated from normal yield tables. In normal stands of western white pine the growing space ratio was approximately the same for all sites at any given age, but the ratios for poor sites were much lower when stands were compared on the basis of average stand diameter. Statistical analysis of the relation between d.b.h. and crown spread showed a high correlation between these measurements.
KEYW Form, development, growing space ratio, growth rate, annual increment, crown area index.

23 AUTH Axelrod, D. I.
DATE 1956
TITL Mio-pliocene floras from west-central Nevada.
PUBL Geology Science 33. Berkeley, CA: University of California. 322 p.
ABST This manuscript includes a brief discourse relating *Pinus wheeleri* to such living white pines as *P. monticola* and *P. strobus*. The occurrence of a pine related to *P. monticola* in the Nevada flora, at no great distance from woodland and chaparral vegetation, scarcely agrees with the ecologic occurrence of its living analog.
KEYW *Pinus wheeleri*, fossil flora.

24 AUTH Bagnell, C. R.
DATE 1975
TITL Species distinction among pollen grains of *Abies, Picea*, and *Pinus* in the Rocky Mountain area (a scanning electron microscope study).
PUBL Review of Palaeobotany and Palynology. 19: 203-220.
ABST Modern pollen grains from several species of *Abies, Picea,* and *Pinus* occurring mainly in the Rocky Mountain region of the United States and Canada were examined using the scanning electron microscope. Distinguishing characteristics for the species were found using systematized observational and photographic methods on extensive collections. Preparation of the samples included acetolysis, critical-point drying to preserve three-dimensional morphology, and carbon-gold coating. The technique employed in preparing the pollen samples is outlined in detail in this paper. Species distinctions were based on types of morphological structures rather than on measurements of the grains or their parts; however, several subjective determinations of shape and proportion proved useful in distinguishing certain species. *Pinus ponderosa* differs from *P. contorta* on the basis of cappula morphology. *Pinus monticola* and *P. albicaulis* can be singled out from the other pines studied and distinguished one from the other by a combination of cappula and cappa characteristics. *Pinus cembroides* is distinguished from the other pines by its characteristic cappa and *P. edulis* by shape, proportion, and attachment of its bladders. Although *P. monophylla* showed no single distinctive morphological feature, it can be separated from the other pines studied by a process of elimination based on several characteristics.
KEYW Pollen morphology.

25 AUTH Bailey, W. H.
DATE 1964
TITL Revegetation in the 1914-1915 devastated area of Lassen Volcanic National Park.
PUBL Corvallis, OR: Oregon State University. Ph.D. dissertation. Dissertation Abstracts 24: 3068.
ABST Western white pine was one of the early pioneers to become established.
KEYW Revegetation of volcanic area, Lassen Peak revegetation.

26 AUTH Baker, F. S.
DATE 1949
TITL A revised tolerance table.
PUBL Journal of Forestry. 47: 179-181.
ABST In this revision of Zon and Graves' (1911) tolerance table for important U.S. trees, western white pine is ranked as first under intolerant western conifers, or (more acceptable to those responding to questionnaire) as first under intermediate.
KEYW Tolerance.

27 AUTH Barnes, B. V.
DATE 1964
TITL Self- and cross-pollination of western white pine: a comparison of height growth of progeny.
PUBL Research Note INT-22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Height growth of 9- to 12-year-old western white pine seedlings from self-pollinated parents was compared with that of seedlings from cross- pollinated parents. Data indicate that growth depression from selfing, previously observed in the nursery, continues undiminished after inbred seedlings are outplanted.
KEYW Self pollination, cross pollination, height growth.

28 AUTH Barnes, B. V.
DATE 1967
TITL Phenotypic variation associated with elevation in western white pine.
PUBL Forest Science. 13: 357-364.
ABST Racial differentiation of *Pinus monticola* associated with elevation was investigated on sample plots selected at elevations ranging from 2,500 to 4,600 feet. Periodic annual height growth was significantly less for trees at 4,600 feet than for trees at elevations ranging from 2,500 to 4,000 feet. Branch angle increased progressively and significantly with increasing elevation. Needle length and cone scale width and length between elevations differed significantly, but the pattern of variation was essentially random. For other attributes, including seed weight, no significant difference was found

between elevations. There were highly significant and moderately strong correlations between many cone and seed traits. In general, cone and seed traits were not significantly correlated with growth rate or branch angle.
KEYW Phenotypic variation, growth rate, branch angle, needle length, cone variation patterns, seed weight.

29 AUTH Barnes, B. V.
DATE 1969
TITL Effects of thinning and fertilizing on production of western white pine seed.
PUBL Research Paper INT-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.
ABST In a 40-year-old western white pine plantation developed as a seed production area, heavy thinning and application of fertilizer in the fall significantly increased strobilus production the following spring. Applying fertilizer increased seed weight and cone length significantly, but thinning did not. Insects severely damaged the cone crop in the thinned stand. This study indicates that abundant seed crops, relatively free from insect damage, may be produced without expensive thinning and area preparation operations.
KEYW Genetic gain, seed production areas, strobilus production, fertilization, seed production rates.

30 AUTH Barnes, B. V., Bingham, R. T.
DATE 1962
TITL Juvenile performance of hybrids between western and eastern white pine.
PUBL Research Note 104. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p.
ABST The growth and performance of *Pinus monticola, P. strobus*, and their hybrids were investigated at several sites in northern Idaho and western Montana. At three sites in northern Idaho, two hybrid progenies were approximately twice as tall and markedly excelled corresponding *P. monticola* progenies (having the same female parents) in height growth at age 8 years. At one site in western Montana none of the few *P. monticola, P. strobus*, and hybrid progenies performed satisfactorily. All except a high-elevation *P. monticola* source from California were severely damaged by snow.
KEYW Hybrids, *Pinus monticola* x *P. strobus*.

31 AUTH Barnes, B. V., Bingham, R. T.
DATE 1963
TITL Cultural treatments stimulate growth of western white pine seedlings.
PUBL Research Note INT-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST An experiment was conducted to determine the effectiveness of cultural treatments (cultivating, fertilizing, and watering in all possible combinations) in stimulating growth rate and inducing strobilus formation in western white pine seedlings in northern Idaho. Although strobilus production was negligible, striking differences in total height and diameter at 12 inches above the ground were attributed to the cultural treatments. The combined three-factor treatment was most effective in stimulating height and diameter growth. Cultivation was the most effective single treatment and the most effective component of double treatments, particularly in stimulating diameter growth. The use of these cultural treatments is a promising method of developing seed orchard trees of sufficient size and vigor to bear large cone crops.
KEYW Cultural treatments, cultivation, watering, fertilization.

32 AUTH Barnes, B. V., Bingham, R. T.
DATE 1963
TITL Flower induction and stimulation in western white pine.
PUBL Research Paper INT-2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.
ABST Several methods of inducing and stimulating strobilus production were tested. These included: (1) top grafting 5-year-old seedling scions, (2) top grafting 6-year-old seedling scions, (3) cultivating, watering, and fertilizing young (average age 11 years) trees, (4) stimulation by fertilization in fruiting age (average 28 years) trees. None of the attempts were successful.
KEYW Flower induction, flower stimulation, top grafting, cultivation, irrigation, fertilization, strobilus production stimulation.

33 AUTH Barnes, B. V., Bingham, R. T., Schenk, J. A.
DATE 1962
TITL Insect-caused loss to western white pine cones.
PUBL Research Note 102. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p.

ABST Insects of three genera, *Conophthorus*, *Dioryctria*, and *Eucosma*, have caused severe loss to cone crops of western white pine in two areas in northern Idaho. The western white pine cone beetle, *Conophthorus monticolae,* destroyed more than 90 percent of the cones on 12 trees from one area during a 6-year period. At a second locality, larvae of *Dioryctria abietella* and *Eucosma rescissoriana* infested 19 percent of the cones on 54 trees in a relatively good seed year and 78 percent in the following, but relatively poor, seed year. Losses varied seasonally.
KEYW Cone insects, *Conophthorus monticolae*, *Dioryctria abietella*, *Eucosma rescissoriana.*

34 AUTH Barnes, B. V., Bingham, R. T., Squillace, A. E.
DATE 1962
TITL Selective fertilization in *Pinus monticola* Dougl. II. Results of additional tests.
PUBL Silvae Genetica. 11: 103-111.
ABST Eight tests involving four female parents and six male parents were made to determine the extent of reproductive discrimination between competing self- and outcross-pollens of western white pine trees. Two seed trees were termed "partially self-fertile." In one completely self-fertile tree selfing exceeded outcrossing when competing pollens were in the ratio 1:1. In the second completely self-fertile tree, selfing predominated when self-pollen was in competition with pollen of one tree (ratio 1:1), but outcrossing exceeded selfing when self-pollen was in competition with the pollen mix. In the two partially self-fertile trees, when outcross and self-pollens were competing in the ratio 1:1, outcross pollen was more effective in yielding germinable seed than self-pollen in practically every test. Albino seedlings in the ratio one white to three green were found to occur in the selfed progeny of partially self-fertile tree 64. A positive correlation between parent tree growth rate and pollen-tube vigor was advanced. Findings could be explained by this relationship in nearly every instance.
KEYW Selective fertilization, seed yield, inbreeding, controlled pollination, self fertility.

35 AUTH Barrett, L. I., Briegleb, P. A., Mark, G. C., Roe, A. L.
DATE 1958
TITL Appendix: criteria for rating productivity.
PUBL In: Timber resources for America's future. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 691-700.
ABST Classifies species according to forest type group. Lists trees per acre, seed source classification, seedbed conditions, percentage of mean annual growth, effective seeding distance.
KEYW Timber classification, mean annual growth, seeding distance.

36 AUTH Base, S. R., Fosberg, M. A.
DATE 1971
TITL Soil-woodland correlation in northern Idaho.
PUBL Northwest Science. 45(1): 1-6.
ABST Site index prediction equations were developed for *Pinus monticola, P. contorta, P. ponderosa*, and *Larix occidentalis* using regression analysis techniques. Correlations were made between soils of unknown productivity and similar soils of known productive capacities. The equation for western white pine is fairly reliable; those for the other three species are less reliable.
KEYW Soil-woodland correlation, site quality.

37 AUTH Bates, C. G.
DATE 1925
TITL The relative light requirements of some coniferous seedlings.
PUBL Journal of Forestry. 23: 869-879.
ABST The minimum light requirement for western white pine seedlings as shown by survival at the end of an 11-month period is listed as 97 percent of full sunlight. Seed weight has a possible influence on ability to survive in weak light.
KEYW Light requirements, seed weight.

38 AUTH Behre, C. E.
DATE 1924
TITL Prediction of yields of young western white pine timber in Idaho.
PUBL Idaho Forester. 6: 32-36.
ABST Yield predictions for a young stand of predominantly western white pine near Clarkia, ID, are given. The predictions were based on a systematic sample of d.b.h. and increment cores. Yield tables for white pine and for white pine-larch mixtures are given.
KEYW Yield prediction, regeneration, reproduction, growth prediction.

39 AUTH Behre, C. E.
DATE 1945
TITL Growing stock, cutting age, and sustained yield.
PUBL Journal of Forestry. 43: 477-485.
ABST Better understanding of the Nation's forest situation requires an appraisal of present stand in relation to the volume of growing stock needed to sustain prospective timber requirements. For a given level of output the required growing stock is a function of cutting age and may be expressed as a multiple of the yield. Growing-stock ratios,

deduced from available yield tables and assumptions as to average cutting ages, indicate that the poorly distributed volume of timber we now have (1945) is not greater than the well-distributed volume of growing stock we shall need in order to maintain the current level of output, to say nothing of attaining a larger potential yield.
KEYW Growing stock, cutting ages, sustained and potential timber requirements.

40 AUTH Bendtsen, B. A.
DATE 1973
TITL Important structural properties of four western softwoods: white pine, sugar pine, western redcedar, and Port Orford cedar.
PUBL Research Paper FPL-191. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 17 p.
ABST The most comprehensive evaluation ever conducted on these four species has provided new values for the important mechanical properties and specific gravity. No species showed a consistent increase or decrease in all properties at either green or air dry moisture condition. However, in each species, at least two important green property values that are the basis for development of structural design properties were changed significantly. Five out of six such property values of white pine changed significantly.
KEYW Wood values, structural properties.

41 AUTH Benea, V., Leandru, L., Nitu, C.
DATE 1964
TITL Physiological and biochemical studies in pine breeding.
PUBL In: Proceedings, FAO World Consultation on Forest Genetics; 1983; Stockholm, Sweden. p. 11-18
ABST A series of physiological and biochemical studies were carried out to determine: respiration intensity, total phosphorus and nitrogen content, amino acids, and carbohydrates. Comparisons were made of species and hybrids.
KEYW *Pinus monticola* x *P. strobus,* species crosses, respiration intensity, phosphorus content, nitrogen content, amino acids, carbohydrates, hybrids.

42 AUTH Benson, R. E., Kirkwold, L. L.
DATE 1967
TITL Market trends for western white pine.
PUBL Research Note INT-65. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST Western white pine has historically been one of the most important timber species harvested in the Rocky Mountain area. This study summarizes changes that have taken place during the past 4 decades in western white pine lumber production, lumber prices, and major manufacturing uses.
KEYW Lumber production, manufacturing, lumber prices, market trends.

43 AUTH Betts, H. S.
DATE 1940
TITL Western white pine (*Pinus monticola*).
PUBL American Woods. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.
ABST This paper, from the "American Woods" series, gives a general description of western white pine. (See revision dated 1954.)
KEYW Description, range, uses, production.

44 AUTH Betts, H. S.
DATE 1954
TITL Western white pine.
PUBL American Woods. Washington, DC: U.S. Department of Agriculture, Forest Service. 6 p.
ABST This paper, from the "American Woods" series, gives a general description of western white pine, including nomenclature, distribution and growth, production, properties, and principal uses.
KEYW Range, products, production, uses, description.

45 AUTH Biddle, P. G., Tinsley, T. W.
DATE 1968
TITL Virus diseases of conifers in Great Britain.
PUBL Nature. 219: 1387-1388.
ABST Virus-like particles were obtained from sap exudates of 4-year-old seedlings showing a severe stem necrosis resulting in defoliation and death of the shoot. Defoliation is a symptom of the virus infection.
KEYW Virus disease, Great Britain, seedling mortality.

46 AUTH Billings, C. L.
DATE 1924
TITL Slash disposal in a privately owned white pine stand.
PUBL Idaho Forester. 6: 23-25.
ABST Reports on an experiment implementing piling and burning for slash disposal on a privately owned white pine stand.
KEYW Slash disposal, fire danger, broadcast burning.

47 AUTH Billings, R. F., Gara, R. I.
DATE 1975
TITL Rhythmic emergence of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) from two host species.

PUBL Annals Entomological Society of America. 68: 1033-1036.
ABST Emergence of adult *Dendroctonus ponderosae* Hopkins from ponderosa pine and western white pine exhibited distinct host-specific patterns under field conditions that appeared closely correlated with ambient temperatures in the latter host species but not in the former. The lower temperature threshold for beetle emergence was ca. 16 °C. Periodicities in emergence from both host species also prevailed under conditions of constant temperature and light, providing evidence of an endogenous rhythm. Ratios of one male to three females, observed during the first week of seasonal emergence from ponderosa pine, appeared to change in favor of males as the season progressed. A more constant 1:2 male to female ratio was maintained to broods emerging from western white pine.
KEYW *Dendroctonus ponderosae*, emergence bark beetles.

48 AUTH Bingham, R. T.
DATE 1972
TITL Station publications in forest genetics and related fields.
PUBL Research Note INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.
ABST Lists 123 Station and Station-connected publications in forest genetics, tree breeding, and related fields, dating from 1921. Revises and updates Roberts, V., USDA Forest Service Res. Note INT-48, 1966. Over one-half of the publications are concerned with white pines (principally *Pinus monticola*), and over one-third deal with various aspects of white pine blister rust resistance.
KEYW Genetics, breeding, bibliography.

49 AUTH Bingham, R. T.
DATE 1973
TITL Possibilities for improvement of western white pine by inbreeding.
PUBL Research Paper INT-144. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 18 p.
ABST *Pinus monticola* seedling mortality, timing and extent of fruiting, strobilus attrition, crossing success, seed yield, and seed weight are compared for 18 selfed lines and their outcrossed half-sib lines. No reproduction barriers are restrictive enough to preclude continued inbreeding. Filled seed yields from second generation inbreeding were low but consistent and large enough to justify continuing an experimental program. Results of experimental single crossing between S_1 lines should guide decision on a practical inbreeding program.
KEYW Pedigree, seed germination, inbreeding.

50 AUTH Bingham, R. T., Hanover, J. W., Hartman, H. J., Larson, Q. W.
DATE 1963
TITL Western white pine experimental seed orchard established.
PUBL Journal of Forestry. 61: 300-301.
ABST Seed orchard management practices for increasing efficiency in mass-production of genetically improved western white pines are under investigation in a new experimental orchard at Sandpoint, ID. Information gained there may soon find application in the operation of nearly 100 acres of grafted seed orchards proposed for practical production of blister rust resistant F_2 seed.
KEYW Seed orchards.

51 AUTH Bingham, R. T., Hoff, R. J., Steinhoff, R. J.
DATE 1972
TITL Genetics of western white pine.
PUBL Research Paper WO-12. Washington, DC: U.S. Department of Agriculture, Forest Service. 28 p.
ABST Summarizes the results of 20 years' research on the genetics of *Pinus monticola*, with particular reference to its palaeo-botany, present botanical range, habitat, growth, floral biology, cone- and seed-yielding ability, self-pollination and selective fertilization, capacity for reproduction by rooting and grafting taxonomy, crossability, hybridization with other species, monoterpene composition, and resistance to insects and diseases. Emphasis is placed on resistance to *Cronartium ribicola* and on the improvement of this trait.
KEYW Genetics, breeding, reproductive behavior, variation, vegetative propagation, chemical constituents, disease survey, stem rusts.

52 AUTH Bingham, R. T., Rehfeldt, G. E.
DATE 1970
TITL Cone and seed yields in young western white pines.
PUBL Research Paper INT-79. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 12 p.
ABST Eighteen years of cone and seed yields from 179, 30- to 50-year-old western white pine representative of 13 geographic localities were compared. Each tree averaged 28 cones per tree, and each cone contained about 104 filled seeds.
KEYW Seed production, cone production.

53 AUTH Bingham, R. T., Squillace, A. E.
DATE 1955
TITL Self-compatibility and effects of self-fertility in western white pine.
PUBL Forest Science. 1: 121-129.
ABST Cone and seed yields and seed germinability following self-pollinations in western white pine were compared with corresponding yields and germinability following cross-pollinations on the same trees. Self-pollinated seedling heights the first, second, and third years were 11, 21, and 21 percent below cross-pollination heights, respectively. Some natural barriers to selfing are not completely effective.
KEYW Self compatibility, selfing barriers.

54 AUTH Bingham, R. T., Squillace, A. E.
DATE 1957
TITL Phenology and other features of the flowering of pines, with special reference to *Pinus monticola* Dougl.
PUBL Research Paper INT-53. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 26 p.
ABST Flowering in 45 young *Pinus monticola* trees was closely observed for up to 6 years. Results were: (1) average dates of first anthesis at low and high elevations were June 27 and July 8, respectively; (2) period of pollen dissemination averaged 8-$^1/_2$ days: period of ovulate flower receptivity 9-$^1/_2$ days; (3) very fruitful individuals had prolonged flowering periods; (4) flowering was delayed about 5 days per 1,000-ft increase in elevation and about 6 days per °F departure of May and June temperatures below normal.
KEYW Flowering, anthesis, pollen dissemination, self pollination, crossing, phenology flowering.

55 AUTH Bingham, R. T., Squillace, A. E., Duffield, J. W.
DATE 1953
TITL Breeding blister-rust-resistant western white pine.
PUBL Journal of Forestry. 51: 163-168.
ABST Summarizes work on development of blister rust resistant western white pine including methods of vegetative propagation.
KEYW Disease resistance, selection, vegetative propagation, intraspecies breeding, grafting.

56 AUTH Bingham, R. T., Squillace, A. E., Patton, R. F.
DATE 1956
TITL Vigor, disease resistance, and field performance in juvenile progenies of the hybrid *Pinus monticola* Dougl. x *Pinus strobus* L.
PUBL Silvae Genetica. 5(4): 104-112.
ABST Juvenile performance of 16 different hybrid progenies from controlled pollinations between *Cronartium ribicola*-resistant selections of *P. monticola* and *P. strobus* is discussed. The progeny exhibited significantly different average height growth rates. Preliminary evaluations indicate that hybrid resistance may be lower than in corresponding intraspecies progenies. Acclimatization of the hybrids remains conjectural.
KEYW Hybrids, hybrid growth.

57 AUTH Bingham, R. T., Wise, K. C.
DATE 1968
TITL Western white pine cones pollinated with 1- to 3-year-old pollens give good seed yields.
PUBL Research Note INT-81. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Filled seed yields of *Pinus monticola* cones from 55 controlled crosses made with 1- to 5-year-old, deep-freeze-stored pollens were compared with yields from other fresh-pollen crosses made on the same trees in the same pollination seasons. Observations covered four pollination seasons, and on the average involved about 11 trees, and 14 stored-pollen and 25 fresh-pollen crosses thereon, per season. One- to 3-year-old pollens gave 52 to 110 percent of the yield observed for fresh pollens, and there was some evidence that 4- and 5-year-old pollens might also be satisfactory for routine use.
KEYW Pollination, pollen storage.

58 AUTH Bingham, R. T., Wise, K. C., Wells, S. P.
DATE 1969
TITL Aberrant cones in western white pine.
PUBL Research Note INT-86. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Two rare cone forms—proliferated and forked—are reported and illustrated for *Pinus monticola*. The latter form may be unique to this species and may be genetically controlled. In addition, genes controlling the forked-cone trait may be linked with recessive genes associated with chlorophyll deficiencies of *P. monticola* foliage.
KEYW Aberrant cones, chlorophyll deficient.

59 AUTH Blair, J. H.
DATE 1946
TITL Frost damage to woodlands on Blairquhan Estate in April 1945.
PUBL Scottish Forest Journal. 60(1): 38-43.
ABST Frost damage occurring April 29, 1945, is summarized for the Blairquhan Estate

conifer hardwood plantations. A discussion follows outlining steps that may prevent future losses.

KEYW Frost damage, genetic selection, natural regeneration.

60 AUTH Blanchette, R. A.
DATE 1979
TITL Cell wall decomposition by *Phellinus (Fomes) pini*.
PUBL Phytopathology. 69(8): 913.
ABST Wood decomposition by *Phellinus (Fomes) pini* in living white pine was investigated using scanning electron microscopy. Preferential loss of lignin resulted in a unique type of cell wall degradation. Macrofibrillar bundles (0.2 to 0.4 mm) remained within the tracheid wall while noncellulosic wall materials were removed. Degradation occurred at appreciable distances from fungal hyphae indicating that a highly diffusable lignin degrading enzyme system is involved. Ray parenchyma cells were completely destroyed. The middle lamella was also selectively degraded. Boundaries between sound and decayed wood were formed by springwood cells and occluded ray parenchyma cells.
KEYW *Phellinus (Fomes) pini*, cell wall degradation, hyphae, lignin, macrofibrillar bundles, ray parenchyma cells, degrading enzyme.

61 AUTH Boisselle, H. J.
DATE 1969
TITL Successful kiln drying of white pine for furniture stock.
PUBL Forest Products Journal. 19(3): 17-20.
ABST The roles humidity and temperature play in the successful kiln-drying of white pine are discussed at some length. Proper control of these two factors during the drying schedule is shown to be the key to minimizing several types of defects. A method for monitoring moisture content is also presented.
KEYW Kiln-drying, furniture stock, drying defects, moisture content.

62 AUTH Bordelon, M. A.
DATE 1978
TITL Some environmental and genetic parameters of cone production in *Pinus monticola* Dougl.
PUBL Moscow, ID: University of Idaho. 124 p. M.S. thesis.
ABST Ovulate strobilus loss was tallied from pollination to harvest. Frost damage and nonpollination were considered to be the major contributing factors in the loss. Trees that had been naturally pruned produced more cones than unpruned trees. Flower loss was family related.
KEYW Ovulate strobilus loss, cone production, pruning, frost damage.

63 AUTH Boyd, R. J., Jr.
DATE 1959
TITL Cleaning to favor western white pine—its effects upon composition, growth and potential values.
PUBL Journal of Forestry. 57: 333-336.
ABST Results of two cleanings to favor western white pine show that: (1) compositional improvements have been maintained at a high level during the 20 years since cleaning; (2) improvement in size and volume of potential crop trees resulted from the reduction in stand densities; and (3) similar cleaning operations under current economic conditions should yield substantial economic benefits.
KEYW Cleaning, stand composition, growth.

64 AUTH Boyd, R. J., Jr.
DATE 1961
TITL Deception Creek Experimental Forest.
PUBL Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Moscow, ID. 3 p.
ABST The Deception Creek Experimental Forest, located in the heart of the Coeur d'Alene National Forest, is dedicated to the development of better timber growing methods in the western white pine type. It is one of two experimental forests in the white pine type maintained for purposes of research and demonstration by the Intermountain Research Station. An index to major research projects is given, many of which include western white pine.
KEYW Deception Creek Experimental Forests.

65 AUTH Boyd, R. J., Jr.
DATE 1969
TITL Some case histories of natural regeneration in the western white pine type.
PUBL Research Paper INT-63. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.
ABST Trends of natural regeneration in some northern Idaho western white pine stands under a variety of silvicultural systems and habitat types are described. On moist sites, characterized by a *Thuja-Tsuga/Pachistima* habitat type, any of the even-aged silvicultural systems resulted in adequate regeneration with desirable species diversity within 5 to 10 years following cutting. Drier sites, represented by the *Abies grandis/Pachistima* habitat type, were characterized by a prolonged regenerative period which

may exceed 20 years regardless of silvicultural method used. Selection cutting on these sites tends to favor nearly pure grand fir reproduction.
KEYW Shelterwood cut, clearcuts, seed tree cut, selection cut, regeneration.

66 AUTH Boyd, R. J., Jr.
DATE 1971
TITL Effects of soil fumigation on production of conifer nursery stock at two Northern Rocky Mountain nurseries.
PUBL Research Paper INT-91. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 19 p.
ABST Soil fumigation has improved production of Douglas-fir, western white pine, Engelmann spruce, and ponderosa pine stock at two Northern Rocky Mountain nurseries. The better fumigation treatments substantially reduced weeds and losses from diseases and insects, and generally resulted in larger stock with improved survival potential. Late summer fumigation with methyl-bromide-based fumigants has provided the most dependable overall improvement in nursery operation.
KEYW Soil fumigation, methyl-bromide, seedling growth.

67 AUTH Boyd, R. J., Jr.
DATE 1980
TITL Western white pine.
PUBL Proceedings Society of American Foresters. 1980: 94-95.
ABST The climatic, edaphic, and physiographic requirements are described.
KEYW Geographic distribution, ecological relationships.

68 AUTH Boyd, R. J., Jr., Deitschman, G. H.
DATE 1964
TITL Development of young western white pine plantations.
PUBL Research Note INT-18. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Study of two young western white pine plantations revealed their growth to be much faster than that of natural stands of comparable age. Data from a third plantation provided additional information on effects of site and density.
KEYW Plantation, site, density, stocking, diameter, height.

69 AUTH Bradner, M., Fullaway, S. V., Jr.
DATE 1927
TITL Size of timber, amount of defect—important factors in lumbering.
PUBL The Timberman. 29(2): 38-40.
ABST Compares values and production costs of sound western white pine logs according to size and position in tree.
KEYW Defect, timber size, lumbering, production costs.

70 AUTH Brandsberg, J. W.
DATE 1966
TITL A study of fungi associated with the decomposition of coniferous litter.
PUBL Pullman, WA: Washington State University. 105 p. Ph.D. thesis.
ABST The kinds and successions of fungi associated with decomposition of litter under *Abies grandis, Pinus monticola,* and *P. ponderosa* on sites located in Latah County, ID, were studied and an additional *P. ponderosa* site located on the Washington State University campus in Pullman, WA, was included in order to contrast fungi from old, well-established sites with those of a stand of more recent origin. A total of 151 species of fungi were isolated from a-0 and a-1 soil horizon materials. These included: 125 *Fungi imperfecti,* 13 *Ascomycetes,* and 10 species of *Phycomycetes.*
KEYW Decomposition of litter, *Fungi imperfecti, Ascomycetes, Phycomycetes.*

71 AUTH Brandsberg, J. W.
DATE 1969
TITL Fungi isolated from decomposing conifer litter.
PUBL Mycologia. 61: 373-381.
ABST A qualitative study was made of the mycofloras involved in the degradation of litter of *Abies grandis, Pinus monticola,* and *Pinus ponderosa* on sites located in northern Idaho. A total of 128 fungi were isolated. While no pronounced differences were noted in the mycofloras of the duff of different tree species, there was an evident succession of fungi as the leaf materials were degraded. Similarities and differences among species found during this study and those found by other investigators are noted.
KEYW Fungi forest litter, mycoflora.

72 AUTH Brewster, D. R.
DATE 1917
TITL Silvical research work in District One.
PUBL Forest Kaimin. Missoula, MT: University of Montana. p. 15-16, 34-35.
ABST The need to have full-time researchers to provide forest management information, data, and facts is presented. The type of data needed is discussed.
KEYW Data information needs.

73 AUTH Brewster, D. R., Larsen, J. A.
DATE 1925
TITL Girdling as a means of removing undesirable tree species in the western white-pine type.
PUBL Journal of Agricultural Research. 31: 268-274.
ABST On areas where seedlings, saplings, and larger trees of the species *Tsuga heterophylla* and *Abies grandis* are present, it is difficult to obtain establishment and growth of the more intolerant desirable species (*Pinus monticola* and *Larix occidentalis*). Girdling, burning, and poisoning are possible methods of disposing of the former species. Girdling with an ax notch in the spring or early summer was the most effective method tested.
KEYW Thinning, girdling.

74 AUTH Brown, J. K.
DATE 1978
TITL Weight and density of crowns of Rocky Mountain conifers.
PUBL Research Paper INT-197. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 56 p.
ABST Relationships between live and dead crown weight and d.b.h. (ranging from 0 to 40 inches), crown length, tree height, and crown ratio are presented for 11 conifer species in the Rocky Mountains. D.b.h. was highly correlated with crown weight; however, for most species, addition of height, crown length, and especially crown ratio improved precision. Site index and stand density improved precision of estimates slightly for about one-half of the species. Crown ratio accounted for most of the differences in crown weight between dominant and intermediate crown classes. Relationships between bole weights and d.b.h. and height are presented for trees up to 4 inches d.b.h.
KEYW Crown weight, crown length, crown ratio, foliage weights, branchwood weights, foliage density, branchwood density.

75 AUTH Brown, N. C.
DATE 1913
TITL Management of western white pine in northern Idaho.
PUBL Proceedings Society of American Foresters. 7-8: 327.
ABST Gives a general summary of current practices and knowledge concerning management of western white pine in northern Idaho.
KEYW Management, range, market, uses, silvicultural characteristics, rotation, yield.

76 AUTH Brundage, F. H.
DATE 1943
TITL Northwest woods have gone to war.
PUBL Journal of Forestry. 41: 654-658.
ABST Shortly after World War I, wood passed out of the picture for aircraft construction and other materials took its place. This article describes the return of wood for aircraft in World War II and the efforts being made to assure an adequate supply of the required quality. In spite of all this drive for war production, the author cautions against forgetting forestry by stopping selective cutting in pine, failing to leave an adequate source of seed supply in Douglas-fir, and easing up on fire protection.
KEYW Aero-grade lumber, log allocation, access roads, forest depletion.

77 AUTH Brush, W. D.
DATE 1951
TITL Knowing your trees: western white pine.
PUBL American Forests. 57: 28.
ABST A general description of western white pine, its uses, pests, and history.
KEYW Identification, range, description.

78 AUTH Buchanan, T. S.
DATE 1936
TITL An alinement chart for estimating number of needles on western white pine reproduction.
PUBL Journal of Forestry. 34: 588-593.
ABST A total of 6,809 measurements of crown length, crown width, and number of needles on young western white pines were made in British Columbia following the 1928 and the 1930 seasonal development. Of this total, 2,923 measurements of trees which were found to be normal in every respect were used in the construction of an alignment chart by the harmonized curves method. This chart permits the determination of number of needles when only crown length and crown width are known. Checking the chart statistically showed the aggregate difference to be 1.43 percent low, and the average deviation to be 39.5 percent, indicating that good results can be secured when measuring large numbers of trees, but that results for individual trees are not too reliable.
KEYW Reproduction, needle number, needle retention.

79 AUTH Buchanan, T. S.
DATE 1948
TITL Study of the mortality of young western white pine trees.
PUBL University of Idaho Bulletin. 43(6): 28-33.
ABST Outlines a cooperative research program on pole blight to investigate range and

distribution, a concise symptomatological picture, progress of the disease, possible causes, and possible silvicultural control methods.
KEYW Mortality, pole blight.

80 AUTH Buchanan, T. S.
DATE 1950
TITL Progress in research on pole blight of western white pine.
PUBL Northwest Science. 24(1): 34-35. Abstract.
ABST Since the inception of this cooperative program in June 1948, the Forest Service has made its lands and facilities available to the more active research agencies, and, through the Spokane Research Center, has initiated a series of cutting plots to test the effect of salvage cuttings on the progress of the disease in the residual stands. The Division of Forest Pathology has instituted an extensive series of inoculations testing the pathogenicity of certain fungi that have been most frequently isolated from pole blighted pines and the School of Forestry (University of Idaho) is making minor tests along similar lines in the summer of 1949 which it plans to continue in 1950 thereby providing the seriously needed information on range and distribution of pole blight. The School of Forestry has completed the field and computational work on 50 dissection trees from which a symptom description of the disease, capable of numerical expression, has been developed. Twenty-one plots have been established on which the progress and development of the disease will be followed. Thirty soils plots have been established in an effort to determine whether or not the disease is correlated with an underlying soils condition. Both the School of Forestry and the Division of Forest Pathology have made beginnings on examinations of the root systems of western white pine and the School of Forestry has initiated studies testing the possible virus aspects of the disease.
KEYW Pole blight, virus research agencies, salvage cuttings, aerial scouting.

81 AUTH Buchanan, T. S., Harvey, G. M., Welch, D. S.
DATE 1951
TITL Pole blight of western white pine: a numerical evaluation of the symptoms.
PUBL Phytopathology. 41: 199-208.
ABST Streaks of dead cambium, generally a few inches wide and several feet long, occurring on the main bole, were the only symptoms found upon detailed dissection of 50 trees that could be considered specific for pole blight. The following observable characteristics were reliable expressions of the severity of pole blight and were utilized in developing the symptom picture: (1) unexplained internodal resinosis on the main bole, (2) dead areas on the main bole, or flattened areas not directly associated with root crotches, (3) length of the last complete year's internode on the leader, (4) overall aggregate length of needle-bearing stem on the leader and upper crown branches, (5) length and color of needles in the upper crown, (6) density of the upper crown. Numerical values have been assigned to variations in these factors in such a way that an apparently healthy tree has a score of 0.0 and a dead tree a score of 4.0. Trees in various stages of pole blight will score between those extremes.
KEYW Pole blight, pole blight symptoms.

82 AUTH Callaham, R. Z.
DATE 1965
TITL Hybridizing pines with diluted pollen.
PUBL In: Proceedings, 8th Southern Conference on Forest Tree Improvement; Savannah, GA. p. 110-111.
ABST Valuable lots of pine pollen can be diluted generally to 30 percent live pollen with no effect on the proportion of seeds that are sound. Dilutions having only 10 or 20 percent viable pollen produced significantly fewer total seeds per cone. The possibilities of diluting pine pollen were studied in the context of a series of interspecific hybridizations carried out at Placerville, CA.
KEYW Hybrids, pollen dilution.

83 AUTH Callaham, R. Z., Steinhoff, R. J.
DATE 1966
TITL Pine pollens frozen five years produce seed.
PUBL In: Joint Proceedings, 2d Genetics Workshop, Society of American Foresters and Seventh Lake States Forest Tree Improvement Conference; October 21-23, 1965; St. Paul, MN. p. 94-101.
ABST This paper reports in vitro germination of pollen and in vivo seed production by pollens stored at –20 °C for up to 5 years. Pollen germinability in vitro indicates pollen viability, but only use of pollen in vivo will show its ability to set cones and to produce sound seeds. Brief freezing of pollen for a few days between extraction and use significantly increased yield of filled seed. Significant reductions in yield of sound seeds occurred after 3 years of freezing.
KEYW Pollen storage, pollen germination.

84 AUTH Callaham, R. Z., Steinhoff, R. J.
DATE 1966
TITL Pine pollens frozen five years produce seed.
PUBL Research Paper NC-6. St. Paul, MN: U.S. Department of Agriculture, Forest Service,

North Central Forest Experiment Station. 8 p.

ABST The ability of pollens of five species of pines to set cones, to produce seed, and to yield filled seed after cold storage up to 5 years was determined. Pollen samples for each species were frozen at –20 °C for a few days and for 1, 2, 3, and 5 years. Two other samples for each species were refrigerated at about 5 °C for 1 and 2 years. Each pollen sample was tested for germination in vitro in the year in which it was used. Brief freezing of pollen for a few days between extraction and use significantly increased yield of filled seed. Storing pollen in a freezer for 1 or 2 years produced fewer filled seeds than fresh pollen. After 3 and 5 years of freezing, the reductions in yield of sound seeds were significant, becoming progressively greater as storage time increased. However, freezing of pollen did not influence its ability to pollinate strobili and to permit seed coats to form.

KEYW Pollen freeze drying, controlled pollination, pollen storage.

85 AUTH Canadian Department of Agriculture

DATE 1953

TITL Pitch moth infestation in western white pine.

PUBL Canadian Department of Agricultural Science Service Bi-monthly Progress Report. 9(1): 3-4.

ABST During November 1952, personnel of the Laboratory of Forest Biology, Vernon, BC, visited a timber sale at Magna Bay, Shuswap Lake, to determine if insects were a factor in the unhealthy condition of western white pine on the area. The inspections revealed that two species of pitch moths, tentatively identified as *Dioryctria zimmermani* and *Vespamima novaroensis*, were present in epidemic proportions. It was estimated that about 50 percent of the stand of white pine over 6 inches d.b.h. was infested in varying degrees. The intensity of the infestation indicated that it extended beyond the area of the timber sale (2,000 acres).

KEYW Pitch moth, *Dioryctria zimmermani, Vespamima novaroensis.*

86 AUTH Carolin, V. M., Coulter, W. K.

DATE 1963

TITL Eradicating European pine shoot moth in commercial nurseries with methyl bromide.

PUBL Research Paper PNW-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 11 p.

ABST Treatments to control European pine shoot moth with methyl bromide were successful on mugho, eastern white, Austrian, lodgepole, and western white pine after long treatment periods.

KEYW European pine shoot moth, methyl bromide, insect control, chemical control.

87 AUTH Castles, J. R.

DATE 1961

TITL The role of white pine in Region 1.

PUBL In: R-1 Annual Blister Rust Control Report 60. Missoula, MT: U.S. Department of Agriculture, Forest Service. 3 p.

ABST White pine lumber production, lumber values, and growth capabilities in northern Idaho were discussed. From a timber quality, growth potential, total value, or stumpage value viewpoint, white pine was viewed as a premium species.

KEYW Inventory data, ownership.

88 AUTH Cech, M. Y.

DATE 1966

TITL New treatment to prevent brown stain in white pine.

PUBL Forest Products Journal. 16: 23-27.

ABST This test showed that chemical brown stain in white pine lumber can be practically eliminated if lumber is treated with an aqueous solution of sodium fluoride immediately after sawing. Heavy brown stain developed in untreated lumber that had been close-piled for 3 days or longer before kiln drying.

KEYW Brown stain, sodium fluoride treatment, kiln drying.

89 AUTH Chapman, J. A.

DATE 1963

TITL Field selection of different log odors by scolytid beetles.

PUBL Canadian Entomologist. 7: 673-676.

ABST Air from a common source was divided and each portion blown through a separate large box containing logs from one tree species. Air from each box was conducted away and released between two window flight traps. Four coniferous tree species were represented in the test. Bark and ambrosia beetles from natural populations responded positively to log odors in the released air. There were differences in the response of beetle species to the log odors represented.

KEYW Scolytidae, log odor.

90 AUTH Chard, R.

DATE 1975

TITL A stand of western white pine at Castle O'er Forest.

PUBL Scotland Forestry. 29(2): 94-101.

ABST Some particulars are given of a small stand of western white pine as further indication that early pruning of five-needled pines reduces

deaths from white pine blister rust. The potential of *Pinus monticola* for high yields of very stable softwood is indicated.
KEYW Scotland, pruning, yield.

91 AUTH Ching, T. M., Ching, K. K.
DATE 1964
TITL Freeze-drying pine pollen.
PUBL Plant Physiology. 39: 705-708.
ABST Two lots of western white pine pollen were air-dried, or stored at 3 degrees for 6 weeks, prior to freeze-drying. Viability and moisture content of control, air-dried, and cold-stored pollen freeze-dried for 15, 30, 45, 60, 90, and 120 minutes were determined. Air-drying for 4 hours, or refrigerating slightly air-dried material for several weeks then freeze-drying for 30 to 60 minutes, was found sufficient to remove free water and retain high viability. Freeze-drying apparently alters the selective permeability of the cellular membrane, as increased amounts of electrolytes, amino acids, carbohydrates, and compounds with maximal absorbance at 260 microns were found in leachate of treated pollen. Change in temperature during freeze-drying of the pollen was recorded.
KEYW Pollen freeze drying.

92 AUTH Ching, T. M., Slabaugh, W. H.
DATE 1966
TITL X-ray diffraction analysis of ice crystals in coniferous pollen.
PUBL Cryobiology. 2: 321-327.
ABST X-ray diffraction analysis was used to discern the relationship between ice formation and killing caused by freezing in pollen. By means of a specially designed low temperature sample holder, ice crystals were detected by x-ray diffraction in Douglas-fir and western white pine pollen containing 36 percent or more water at about –25 °C. Pollen samples with detectable ice crystals were killed by the low temperature. The viability of some pollen samples containing about 30 percent water was reduced by freezing but without detectable ice crystals. This indicates a possibility of separating ice crystal formation and other effects caused by freezing temperatures in biological materials.
KEYW X-ray diffraction analysis, ice crystals, pollen mortality, water content, seed germination.

93 AUTH Chow, S. Z.
DATE 1971
TITL Determining veneer surface inactivation by a reflectance colorimeter.
PUBL Forest Products Journal. 21: 19-24.
ABST The color-intensity difference of veneer surfaces before and after drying, measured with a reflectance colorimeter in the 520 mμ region, was found to relate to the bond quality of plywood made from the veneers of three softwood species: western white pine, western white spruce, and coast Douglas-fir; and one hardwood, trembling aspen. Shear strength of plywood decreased as the color-intensity difference increased. The wood failure percentage decreased with increasing color-intensity difference which depended on the wood species. The wood failure then increased as the color-intensity difference increased as a result of degradation of the fibers on the wood surface. The present method offers a technique for evaluating the severity of the effect of veneer drying conditions on surface inactivation. A suitable drying schedule can be developed that will reduce poor bonds to an acceptable level.
KEYW Veneer surface, bond quality, color intensity.

94 AUTH Clark, J. W.
DATE 1957
TITL Comparative decay resistance of some common pines, hemlock, spruce, and true fir.
PUBL Forest Science. 3(4): 314-320.
ABST Heartwood samples from 14 coniferous tree species were exposed to decay by *Poria monticola*, *Lensites sepiaria*, and *L. trabea*, and then rated according to comparative resistance. The range of resistance among samples of the same woods was shown to be greater for those species exhibiting greater resistance when compared with species of lesser resistance.
KEYW Decay fungi, decay resistance, decay resistance rating.

95 AUTH Cline, R. G.
DATE 1974
TITL Seasonal, diurnal, and spatial water use and water relations of selected forest species.
PUBL Pullman, WA: Washington State University. 68 p. Ph.D. thesis.
ABST Soil moisture, leaf diffusive resistance, leaf water potential, and leaf osmotic potential measurements were made on the soil, one tree species, and three woody brush species on north and south aspects in the Priest River Experimental Forest of northern Idaho. Soil moisture losses appeared to be related to the energy loading associated with aspect, vegetation type, and the maximum springtime water content of the soils. *Acer glabrum* and *Pinus monticola* occurred on both aspects. *Alnus sinuata* and *Physocarpus*

malvaceus occurred only on north and south aspects, respectively. Lower water loss rates were observed on a fully occupied north aspect site dominated by coniferous tree species. The *Pinus* on this site attained osmotic and leaf water potentials near –25 bars and leaf diffusive conductance near 0.06 cm/s. *Pinus* maintained a uniform osmotic potential between –20 and –25 bars throughout the year which appeared to fluctuate during the growing season in accordance with incident solar radiation. Leaf diffusive conductance appeared to be controlled during the day by a combination of atmospheric demand, soil moisture availability, and plant adaptation to water stress. Stomatal control of leaf water potential was evident in *Pinus* on both aspects.

KEYW Water use, water relations, soil moisture, leaf osmotic potential, leaf water potential.

96 AUTH Cline, R. G., Campbell, G. S.
DATE 1976
TITL Seasonal and diurnal water relations of selected forest species.
PUBL Ecology. 57: 367-373.
ABST Leaf diffusive conductance, leaf water potential, and leaf osmotic potential measurements were made on one tree species and three woody brush species on north and south aspects in the Priest River Experimental Forest of northern Idaho. Douglas maple (*Acer glabrum*) and western white pine (*Pinus monticola*) occurred on both aspects. Sitka alder (*Alnus sinuata*) and mallow ninebark (*Physocarpus malvaceus*) occurred only on north and south aspects, respectively. The *Pinus* on the south aspect attained osmotic and leaf water potentials near –25 bars and leaf diffusive conductances near 0.06 cm/s. The pines maintained a uniform osmotic potential between –20 and –25 bars throughout the year. Stomatal control of leaf water potential was evident in pines on both aspects.
KEYW Diffusion resistance, Idaho, osmotic potential, water potential.

97 AUTH Cobb, F. W., Miller, D. R.
DATE 1968
TITL Hosts and geographic distribution of *Scirrhia pini*, the cause of red band needle blight in California.
PUBL Journal of Forestry. 66: 930-933.
ABST *Scirrhia pini* was first identified as the cause of a needle disease of pine in California in January 1966. Over 300 plantings, natural stands, and nurseries were subsequently examined to determine the geographic and host range of the fungus. Eight infection centers were found—all in plantations or ornamental plantings in four areas along the northern coast. The fungus was found on *Pinus radiata*, *P. attenuata*, *P. attenuata* x *radiata*, and *P. contorta*. A fungus closely resembling *S. pini* was found on native *P. monticola* in northern California and has tentatively been identified as *Lecanosticta* sp.
KEYW *Scirrhia pini*, red band needle blight, *Lecanosticta*.

98 AUTH Coffen, D. O., Bordelon, M. A.
DATE 1981
TITL Stem breakage effect on cone and pollen production in *Pinus monticola* (Dougl.).
PUBL Research Note INT-312. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Two studies in a western white pine blister rust resistance breeding arboretum/seed orchard examined the effect of stem breakage on cone and pollen production. Research was based on 4 years of data from 1,529 trees 15 to 29 years of age. Cone and pollen production were increased by breakage of the main stem in the upper crown. Top pruning may be a viable technique for stimulating flowering in seed orchards of western white pine.
KEYW Cone production, pruning for cone production.

99 AUTH Copeland, O. L., Jr.
DATE 1956
TITL Preliminary soil-site studies in the western white pine type.
PUBL Research Note 33. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Results of this study suggest a strong relationship between certain easily determined soil characteristics and site index in the western white pine type. Soil characteristics used in this analysis were effective depth, depth to zone of greatly reduced permeability, and available water-holding capacity.
KEYW Soil characteristics, site index, soil depth, water-holding capacity.

100 AUTH Copeland, O. L., Jr.
DATE 1958
TITL Soil-site index studies of western white pine in the Northern Rocky Mountain region.
PUBL Proceedings Soil Science Society of America. 22: 268-269.
ABST This paper reports results of a study on 37 plots that show the relationships of certain physical soil properties to site index (at age

50) of western white pine. Site index is correlated significantly with effective soil depth, depth to the zone of reduced permeability, and the available water-holding capacity of the top 3 feet of soil. Regression equations and confidence limits at the 5 percent level of significance are included. Applications of these relationships in forest management are discussed.

KEYW Soil-site index, site index, soil properties.

101 AUTH Copeland, O. L., Jr., Leaphart, C. D.
DATE 1955
TITL Preliminary report on soil-rootlet relationships to pole blight of western white pine.
PUBL Research Note 22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Results of a coordinated soil-rootlet mortality study in 1954 indicated that the severity of the pole blight disease of western white pine is significantly correlated with certain physical soil characteristics and rootlet mortality.
KEYW Soil root relationships, pole blight.

102 AUTH Copes, D. L.
DATE 1980
TITL Anatomical symptoms of graft incompatibility in *Pinus monticola* and *P. ponderosa*.
PUBL Silvae Genetica. 29: 77-82.
ABST Internal symptoms of graft incompatibility were examined in unions of 6-month to 8-year-old ponderosa and western white pine grafts. Internal symptoms in both species could be detected in the second and third growing seasons following grafting. Common incompatibility symptoms were phloem and cortex necrosis, suberization, internal periderm formation, and invaginated xylem areas.
KEYW Graft rejection, vegetative propagation, seed orchards.

103 AUTH Cox, W. T.
DATE 1911
TITL Reforestation on the National Forests.
PUBL Bulletin 98. Washington, DC: U.S. Department of Agriculture, Forest Service. 57 p.
ABST Western white pine was considered a very valuable timber tree in certain portions of the Northwest in 1911. Characteristics noted were: It grows rapidly, produces heavy stands of valuable timber, and may be grown on rough, steep mountainsides. Seed of this species is not easily obtained as a general rule, so that it is necessary to do some planting. In nurseries the seed comes up unevenly and therefore requires treatment, such as stratification every winter, or soaking before being sown. This bulletin recommends that western white pine should be used extensively in reforestation work of the National Forests of northwestern Montana at altitudes of from 3,000 to 5,500 feet, throughout northern Idaho at similar altitudes, and in western Washington below 4,500 feet. Every effort should be made to obtain larger quantities of seed.
KEYW Reforestation, seed collection, direct seeding, seed cost, seed germination, seed per acre, seed yield, seed extraction, seed storage, rodents that feed on seed, rodent control.

104 AUTH Critchfield, W. B., Krugman, S. L.
DATE 1967
TITL Crossing the western pines at Placerville, California.
PUBL Seattle, WA: University of Washington Arboretum Bulletin. 30(4): 78-81.
ABST The results of hybridizing the western pine species by the Institute of Forest Genetics are described and discussed. It has been found that the hard (yellow) pines can generally be crossed successfully only with similar species native to the same part of the world. In contrast, the soft (white) pines of the Western Hemisphere have been crossed successfully with soft pines of the Eastern Hemisphere. The hybrids produced by the institute have been found to have value in both the field of forestry and in improving man's environment.
KEYW Hybrids.

105 AUTH Critchfield, W. B., Little, E. L., Jr.
DATE 1966
TITL Geographic distribution of the pines of the world.
PUBL Miscellaneous Publication 991. Washington, DC: U.S. Department of Agriculture, Forest Service. 97 p.
ABST Range maps, a short description of the pines of the world, and selected citations are included.
KEYW Geographic distribution.

106 AUTH Cummings, L. J., Kemp, P. D.
DATE 1940
TITL Forest increment in north Idaho.
PUBL Forest Survey Release 18. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 74 p.
ABST The total land area in northern Idaho is approximately 13 million acres, of which more than 10 million was forest land in 1940. Of this, almost half was unreserved commercial forest in a growing status. The current

annual increment in growing unreserved commercial forests amounted to 636 million bd ft, of which 165 million bd ft or 26 percent was white pine. Current annual drain of timber from the commercial forest (both growing and nongrowing) averaged 712 million bd ft, of which 366 million or 51 percent was white pine. Tables of net current annual board foot increment are given by forest type for counties of northern Idaho.
KEYW Forest increment.

107 AUTH Daubenmire, R.
DATE 1952
TITL Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification.
PUBL Ecological Monographs. 22: 301-330.
ABST The conifer-dominated forests of northern Idaho and adjacent Washington are classified into 13 climax plant associations, divided among four vegetation zones. The associations recognized reflect primarily the reproductive abilities of vascular plant species in the face of competition. Soil pH is closely related to the association sequence, and cation capacity shows a slight tendency to increase upward through the altitudinal series. Moisture equivalent and percentage saturation with hydrogen ions show little relationship to the vegetation matrix. Some practical applications of the findings to forest and wildlife management are suggested. *Pinus monticola* is listed in the following associations (habitat types): *Abies grandis/Pachistima myrsinites*; *Thuja plicata-Tsuga/Pachistima myrsinites*; *Thuja plicata/Pachistima myrsinites*; *Thuja plicata-Tsuga/Oplopanax horridum*; *Picea engelmannii/Pachistima myrsinites*.
KEYW Vegetation classification, habitat type, ecologic classification, climax association, vegetation association.

108 AUTH Daubenmire, R.
DATE 1953
TITL Classification of the conifer forests of eastern Washington and northern Idaho.
PUBL Northwest Science. 27: 17-24.
ABST Western white pine is listed in the following tree unions: major seral role in all *Thuja plicata* and *Picea engelmannii* unions; minor seral role in the *Abies grandis/Pachistima myrsinites* union.
KEYW Habitat type, vegetative classification, tree unions.

109 AUTH Daubenmire, R.
DATE 1953
TITL Nutrient content of leaf litter of trees in the Northern Rocky Mountains.
PUBL Ecology. 34: 786-793.
ABST Nutrient content of *P. monticola* leaf litter from various habitat types ranged as follows: nitrogen, 0.45-0.59 percent (average 0.54 percent); phosphorus, 0.06-0.10 percent (average 0.07 percent); potassium, 0.18-0.28 percent (average 0.22 percent); calcium, 0.55-0.90 percent (average 0.55 percent).
KEYW Leaf litter, leaf litter nutrient content, leaf litter nitrogen, leaf litter phosphorus, leaf litter potassium, leaf litter calcium.

110 AUTH Daubenmire, R., Daubenmire, J.
DATE 1968
TITL Forest vegetation of eastern Washington and northern Idaho.
PUBL Bulletin 60. Pullman, WA: Washington State Agricultural Experiment Station.
ABST Data on population structure of trees, dominance, and frequency among shrubs and herbs, responses to disturbance, animal life, topography, soil, and total known geographic distribution are given. A key is presented for the identification of habitat types. Concepts discussed in relation to the data obtained include the principle of competitive exclusion, continuity of variation, species diversity, and the synecologic significance of basal area.
KEYW Habitat types, population structure.

111 AUTH Davidson, R. W.
DATE 1950
TITL A western white pine twig canker.
PUBL Plant Disease Reporter. 34: 99.
ABST The fungus *Curcurbidothis pithyophila* was collected on twigs of *Pinus monticola* near Nakusp, BC, August 29, 1949. This fungus was fruiting on numerous cankered areas of small twigs in the lower crown of one pole-sized tree. A second specimen was collected by E. P. Meinecke and J. S. Boyce on twigs of *Pinus monticola* in Columbia National Forest (now the Gifford Pinchot National Forest), WA, in August 1942. This indicates that it may be widespread in the western white pine area. No information is available regarding its prevalence or pathological importance.
KEYW *Curcurbidothis pithyophila*, twig canker.

112 AUTH Davidson, R. W., Robinson-Jeffrey, R. C.
DATE 1965
TITL New records of *Ceratocystis europhioides* and *C. huntii* with *Verticicladiella* imperfect stages from conifers.
PUBL Mycologia. 57: 488-490.
ABST Collection of *C. huntii* was made on standing dead *P. monticola* infested with *Dendroctonus ponderosae* and ambrosia beetles at

Mount St. Helens, WA, July 1962. Perithecia were common on beetle-killed trees.
KEYW *Ceratocystis huntii, Verticicladiella,* imperfect stage, *Dendroctonus ponderosae.*

113 AUTH Davis, K. P.
DATE 1936
TITL Test of pruning equipment and methods in western white pine.
PUBL Applied Forestry Note 76. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 9 p.
ABST The best all-around tool of the group tested was the 12-inch hand saw. For most high pruning work in western white pine, the pole saw seems preferable to the ladder method. The ladder method is advisable only where limbs to be cut are large and where the density of the stand is such that a ladder can be transported with reasonable ease through the woods.
KEYW Pruning equipment, pruning methods.

114 AUTH Davis, K. P.
DATE 1940
TITL Economic aspects of managing western white pine forests.
PUBL Northwest Science. 14: 26-32.
ABST In 1940, the Government faced an increasingly larger management problem as forest lands reverted from private ownership. The future of white pine was a big question mark, but the best guess was that white pine sawlogs would continue to be the main money crop and the economic aspects of public forestry were going to demand more and more thorough consideration. Merchantable yields per rotation are given for one-cut and four-cut management plans.
KEYW Economics, merchantable yield, management plans.

115 AUTH Davis, K. P.
DATE 1942
TITL Economic management of western white pine forests.
PUBL Technical Bulletin 830. Washington, DC: U.S. Department of Agriculture, Forest Service. 78 p.
ABST A case analysis of the cost of growing western white pine forests on a long-term basis was presented. Significant conclusions from this analysis were: (1) the general superiority of a partial-cutting over a single-cutting plan of management; (2) the financial difficulties resulting from a market for only one species, western white pine, in a forest of several species; (3) the complete dependence on western white pine as the pay species in the region; (4) with a fully regulated forest operated on a partial-cutting plan, estimated returns slightly exceeded direct costs, indicating that in the long run the public can grow white pine forests on a nonprofit basis; (5) opportunities for private investment in long-time timber growing are slight.
KEYW Economic management.

116 AUTH Davis, K. P., Klehm, K. A.
DATE 1939
TITL Controlled burning in the western white pine type.
PUBL Journal of Forestry. 37: 399-407.
ABST Controlled burning was a highly controversial procedure, but the authors show that under certain conditions when adequate precautionary measures are taken it has a definite place in western white pine forest management. The authors describe the conditions under which it is useful, the precautionary measures that must be taken, the results that may be expected, and the cost of the operation.
KEYW Controlled burning, broadcast burning.

117 AUTH Deitschman, G. H.
DATE 1966
TITL Diameter growth of western white pine following precommercial thinning.
PUBL Research Note INT-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Precommercial thinning treatments of western white pine stands in northern Idaho were broadly classified as heavy thinning and light-to-moderate thinning. Data from periodic measurements of 35 plots, including unthinned control plots, were analyzed for differences in the diameter growth of potential crop trees. Only heavy thinning produced a significant response. Although the average diameter growth increase did not exceed 0.03 inch per year, stands thinned at 55 to 65 years of age have maintained this advantage for periods up to 40 years.
KEYW Diameter growth, thinning precommercial.

118 AUTH Deitschman, G. H., Green, A. W.
DATE 1965
TITL Relations between western white pine site index and tree height of several associated species.
PUBL Research Paper INT-22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 28 p.
ABST Records from 108 permanent plots in northern Idaho western white pine stands were analyzed to develop methods for estimating

comparative height-growth capabilities among major species represented. Equations and graphs published here permit prediction of average dominant-codominant height of five associated species from site data that include stand age and white pine height or site index. Other equations provide estimates of white pine site index from known age and height of the alternate species. Many of the source data come from plots in unmanaged second-growth stands; hence, species-height relations shown here might differ from those in plantations or stands under management.

KEYW Site index, comparative height.

119 AUTH Deitschman, G. H., Pfister, R. D.
DATE 1973
TITL Growth of released and unreleased young stands in the western white pine type.
PUBL Research Paper INT-132. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.
ABST Effects of release by removal of a residual overstory and by cleaning treatments were measured over a 30-year period in young mixed-conifer stands on moist sites in northern Idaho. Increasing time of overwood retention caused rapid loss of the more intolerant species and corresponding reduction in subsequent alternatives for crop-tree selections. Cleaning effectively promoted the growth of leave trees, principally western white pine, but the amount and duration of benefit was decreased by an aggressive reappearance of tolerant and intolerant species, especially in heavily cleaned plots.
KEYW Pruning, mixed stand.

120 AUTH Denton, R. E.
DATE 1960
TITL Association of aphids of the genus *Pineus* with needle blight of western white pine.
PUBL Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID. 18 p.
ABST Abnormal symptoms of crown deterioration, or needle blight, reached serious proportions in western white pine stands in the Inland Empire by 1960. Preliminary investigations showed that needle blight is a complex problem involving both fungi and insects; aphids of the genus *Pineus* were one of the suspected possible causes of needle blight. Studies indicated that one undetermined species of *Pineus* apparently is correlated with crown deterioration symptoms. It is distinguished by the scalelike appearance of the nymphs. This aphid not only is confined to the lower portions of tree crowns, where symptoms of needle blight become evident first, but it is more numerous on trees in advanced stages of crown deterioration. Data showed that the number of aphids on a twig is not excessive, in the sense of being massed. This suggests that if aphids are responsible for needle blight of western white pine they must inject a toxin into the shoots or else they are carriers of a disease organism.
KEYW Needle blight, aphids, *Pineus*.

121 AUTH Denton, R. E., Leaphart, C. D.
DATE 1959
TITL Symptoms of abnormal crown deterioration in western white pine stands.
PUBL Research Note INT-69. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST The cause of crown deterioration reported here is still undetermined. This paper presents information assembled in 1958 concerning the nature of the problem, describes the symptoms and characteristics of affected trees, and suggests what research may be necessary to determine causative agent or agents.
KEYW Crown deterioration, pole blight, aphids, *Pineus, Bifusella, Lophodermium.*

122 AUTH Deuber, C. G.
DATE 1942
TITL The vegetative propagation of eastern white pine and other five-needled pines.
PUBL Journal of Arnold Arboretum. 23: 19.
ABST The rootings of numerous collections of dormant stem cuttings of *Pinus strobus* were tested as well as those of lesser numbers of cuttings of *P. monticola, P. parviflora, P. flexilis, P. koraiensis, P. peuce, P. cembra,* and *P. lambertiana*. Low rooting (5.5 percent) occurred in one collection of cuttings from one tree of *P. monticola.*
KEYW Rooting.

123 AUTH Dickerman, M. B.
DATE 1947
TITL Lumber production gains in the Northern Rocky Mountain Region.
PUBL Research Note 53. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Western white pine figures for the Northern Region were 242,960 thousand bd ft.
KEYW Production lumber.

124 AUTH Dickerman, M. B.
DATE 1947

TITL 1946 - a peak year in pole production.
PUBL Research Note 54. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Pole production for western white pine was 390 poles, less than 0.1 percent of the total produced.
KEYW Production poles.

125 AUTH Dickerman, M. B.
DATE 1949
TITL Lumber production tops 24-year record in Northern Region.
PUBL Research Note 75. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Lumber production for western white pine is listed as 269,836 thousand bd ft in the Northern Region of the Forest Service during 1948.
KEYW Production lumber.

126 AUTH Doll, G. B.
DATE 1940
TITL Grazing in relation to coniferous and vegetational reproduction in the cut-over white pine areas of the Clearwater drainage of northern Idaho.
PUBL Moscow, ID: University of Idaho. 85 p. M.S. thesis.
ABST Past grazing practices in this region have allowed some areas to be heavily grazed over a long period of time while others have remained virtually untouched. A study of these areas reveals the changes that have taken place and also suggests a type of management that may prevent either extremes in the future. The degree to which a given area may be grazed should be based on factors leading to a sustained yield management plan whether this management is primarily to perpetuate timber reproduction or forage for livestock. In this white pine region, cut-over areas should be grazed to obtain complete utilization of the forage "crop" present without eliminating desirable forage species or unduly injuring coniferous reproduction.
KEYW Grazing, reproduction.

127 AUTH Dominik, J.
DATE 1975
TITL Insect pests and parasitic fungi occurring on western white (*Pinus monticola*), pitch (*P. rigida*), and jack (*P. banksiana*) pines in the Experiment Forest at Rogow.
PUBL Sylvan. 119(11): 29-34.
ABST The purpose of this work was to determine the degree of intensity of damage caused by indigenous insects, mammals, and fungi in young plantations, thickets, and older stands of *Pinus monticola, P. rigida,* and *P. banksiana,* when compared with the damage caused by these organisms in *P. sylvestris* stands of a comparable age. It was found that from the viewpoint of forest protection a considerable resistance against *Lophodermium pinastri*, significantly lower susceptibility to attacks by *Rhyacionia buoliana* and *Exoteleia dodecella* are advantages of *P. monticola* when compared with *P. sylvestris*. On the other hand, the high susceptibility to *Cronartium ribicola* is a negative feature of *P. monticola*. Species of pines of North American origin are by far more frequently damaged by game.
KEYW Insect pests, parasitic fungi, Poland, resistance, *Lophodermium pinastri, Rhyacionia buoliana, Exoteleia dodecella,* game damage.

128 AUTH Duffield, J. W., Righter, F. I.
DATE 1953
TITL Annotated list of pine hybrids made at the Institute of Forest Genetics.
PUBL Research Note 86. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 9 p.
ABST The following observations are made concerning *P. monticola:* x *P. strobus*—of special interest because it has outgrown both parent species; x *P. griffithii*—outgrows western white pine and appears less susceptible to blister rust, more drought resistant than Himalayan white pine, but may not be completely cold hardy; x *P. peuce*—no faster growth than western white pine but may combine cold hardiness and moderate resistance to blister rust; x (*peuce* x *strobus)*—grows about the same as *monticola* x *strobus;* blister rust resistance tests incomplete.
KEYW Hybrids, *Pinus monticola* x *P. strobus*, *Pinus monticola* x *P. griffithii*, *Pinus monticola* x *P. peuce*, *Pinus monticola* x (*P. peuce* x *P. strobus*).

129 AUTH Duffield, J. W., Snyder, E. B.
DATE 1958
TITL Benefits from hybridizing American forest tree species.
PUBL Journal of Forestry. 56: 809-815.
ABST Discusses reasons for breeding hybrids and reviews accomplishment in this field of research.
KEYW Hybridization, hybrid vigor, interspecific hybridization.

130 AUTH Ehrlich, J.
DATE 1939

TITL A preliminary study of root diseases in the western white pine type.
PUBL Station Paper 1. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 66 p.
ABST In the areas sampled (on the Coeur d'Alene National Forest, ID) root diseases were common in mature western white pine, the most common being shoestring root rot caused by *Armillaria mellea,* a fungus which is apparently a widespread saprophyte in the soils of the white pine type. Because evidence of root infection by this fungus was found in apparently healthy trees as well as in obviously unhealthy and dying trees, and because increment reductions attributable to infection have occurred for many years, it was concluded that infection may be of long standing in certain trees. The following data are included: increment above roots with most and with least infection; percentage of trees infected in three site-quality classes; percentage of trees infected in four tree-height classes; percentage of trees infected in three site-moisture classes; percentage of trees infected in three classes based on number of snags and stumps within a half chain; crown color and degree of root infection; density of crown and degree of root infection; height, aspect, site quality, and site moisture for beetle-attacked trees; incidence of infection by *A. mellea* in beetle-attacked trees.
KEYW *Fomes annosus*, height, site quality, site moisture, foliage color, root collar, density, mountain pine beetle, root diseases, *Armillaria mellea.*

131 AUTH Ehrlich, J., Baker, L. K.
DATE 1942
TITL Preliminary study of dying of young white pine on Coeur d'Alene and Kaniksu Forests.
PUBL Report to files, University of Idaho and U.S. Department of Agriculture, Forest Service. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID. 67 p.
ABST The purpose of this study was to determine the cause of mortality of white pine. The authors could find no convincing evidence of any obvious cause. They provide two explanations: (1) that mortality represented merely the natural removal of white pine from marginal sites; (2) that mortality was the result of attacks by some fungus or insect or combination of organisms, either indigenous or locally new, aided perhaps by recently lowered resistance of the tree, especially on suboptimal sites, resulting from recently unfavorable weather. The following data are included: d.b.h., height, age, condition of crown and foliage grouped by health of tree, break in increment by year, condition of trunk and roots by individual and area, moistness of site and soil texture, soil profile depth, color, and constituents and parent material, fungi isolated and cultured from diseased trees (*Cryptosporium, Endobotryella,* and *Scopularia*).
KEYW Tree mortality, crown condition, root condition, soil texture, *Cryptosporium, Endobotryella, Scopularia,* trunk condition, soil profile.

132 AUTH Eis, S.
DATE 1976
TITL Association of western white pine cone crops with weather variables.
PUBL Canadian Journal of Forest Research. 6: 6-12.
ABST Records of western white pine cone counts for 21 years were analyzed with seven meteorological variables to find if any combinations of available weather factors were associated with the induction of reproductive buds and successful development of the strobili. The weather in three periods before the physical initiation of the potentially reproductive cycle showed association with cone counts: (1) sunny weather in June, 39 months before cone maturation; (2) warm, sunny, dry weather in September and October, 36 and 35 months before cone maturation; and (3) warm, sunny, dry weather with wide daily temperature range in June and July, 27 and 26 months before cone maturation, appeared to promote differentiation of potentially reproductive buds. During and after the initiation of bud primordia, the weather in four periods appeared to be associated with cone production: (1) warm and possibly wet weather in August, September, and October, 25 to 23 months before cone maturation; (2) rain in the third quarter of July, 4 weeks after pollination and 14 months before cone maturation; (3) warm temperatures in September, October, and November, 12 to 10 months before cone maturation; and (4) sunny, warm, dry weather in May, 4 months before cone maturation, appeared to be beneficial to cone development.
KEYW Cone crops, weather.

133 AUTH Eis, S., Garman, E. H., Ebell, L. F.
DATE 1965
TITL Relation between cone production and diameter increment of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), grand fir (*Abies grandis* (Dougl.) Lindl.) and western white pine (*Pinus monticola* Dougl.).
PUBL Canadian Journal of Botany. 43: 1533-1539.

ABST Cone count records for a 28-year period on 80 Douglas-fir, 14 grand fir, and nine western white pine were statistically analyzed with the annual diameter increment to evaluate the relationship between cone and wood production. The width of annual rings was depressed only during the years of cone production, suggesting that carbohydrates used in cone development were supplied from current photosynthesis rather than from stored reserve. The initiation of reproductive buds did not appear to be dependent on the level of carbohydrates in a tree, and the role of carbohydrates was probably only that of nutrition during cone development. Maturing cones did not exhibit any inhibitory effect on initiation of new flowering buds. Different species may require a different combination of climatic factors for initiation of flowering buds.
KEYW Cone production, diameter increment, annual ring width, annual ring index, carbohydrates.

134 AUTH Eslyn, W. E., Kirk, T. K., Effland, J. J.
DATE 1974
TITL Changes in the chemical composition of wood caused by six soft-rot fungi.
PUBL Phytopathology. 65: 473-476.
ABST Standardized blocks of alder, poplar, and pine were decayed by six soft-rot fungi (*Graphium* sp., *Mondicys* sp., *Paecilomyces* sp., *Papulospora* sp., *Thielavia territris*, and *Allesheria* sp.), all of which had been isolated from pulp chip storage piles. Samples of the woods at different weight losses were analyzed for lignin, glucan (cellulose), xylan, and mannan (hemicelluloses) to allow calculation of the depletion in these major components caused by the fungi. Carbohydrates were depleted faster than lignin in the alder and poplar, cellulose usually faster than the major hemicellulose (xylan). Lignin, which was analyzed by the "sulfuric acid" method, was depleted by all the fungi. Pine was decayed significantly by three of the fungi, and only to low weight losses (15 percent or less) by the other three (*Paecilomyces* sp., *Papulospora* sp., and *Thielavia terrestris).* Analysis of blocks that were decayed showed that lignin was depleted faster than the cellulose or the hemicelluloses by *Paecilomyces* sp. and *Allescheria* sp.
KEYW Wood decay, thermophilic fungi, chemical composition wood, soft-rot fungi.

135 AUTH Evenden, J. C.
DATE 1921
TITL Forest insect control—need for careful surveillance of white pine stands of Idaho and Montana.
PUBL District 1 Applied Forestry Note 11. Missoula, MT: U.S. Department of Agriculture, Forest Service. 3 p.
ABST Mountain pine beetle started to increase on the Coeur d'Alene National Forest in 1919. This note stresses the need for insect surveys to detect extent of damage of mountain pine beetle and western pine beetle and methods for conducting surveys.
KEYW Mountain pine beetle, western pine beetle, insect survey.

136 AUTH Evenden, J. C.
DATE 1930
TITL Economic status of forest insects in the Northern Intermountain Region.
PUBL Northwest Science. 4: 51-54.
ABST Notes that mountain pine beetle in western white pine in northern Idaho had been steadily increasing. Except for the Coeur d'Alene Forest, control measures were considered inadvisable because of the magnitude of the infestation.
KEYW Mountain pine beetle, insects.

137 AUTH Evenden, J. C.
DATE 1930
TITL Insects and forest protection.
PUBL Idaho Forester. 12: 14-15, 61.
ABST Gives a summary of current philosophy (as of 1930) concerning insects and forest protection, lists many of the common forest insect problems, and emphasizes need for more consideration of the insect problem by foresters and the public in general. White pine is mentioned as one of the species demanding more attention from the protection standpoint.
KEYW Insects, western pine beetle.

138 AUTH Evenden, J. C.
DATE 1935
TITL A forest insect problem.
PUBL Idaho Forester. 17: 12-13.
ABST The author advocates artificial control to restore proper biological adjustment and use of silvicultural practices for long term control of the mountain pine beetle in western white pine.
KEYW *Dendroctonus ponderosae*, insects, silvicultural control (insects), resistance (insects), *Armillaria mellea*, parasites.

139 AUTH Evenden, J. C., Bedard, W. D., Struble, G. R.
DATE 1943
TITL The mountain pine beetle, an important enemy of western pines.
PUBL Circular 664. Washington, DC: U.S. Department of Agriculture, Forest Service. 25 p.

ABST From 1930 to 1939, the annual loss of merchantable white pine as a result of mountain pine beetle activity in Idaho and Montana amounted to 91 million bd ft. The successful management of white pine forests requires consideration of the important role played by the mountain pine beetle. As insect-killed white pine are seldom replaced by the same species, this change in timber type leaves a forest of different composition, usually of an inferior species, requiring a reorganization of management plans. Suggested control in white pine was peeling, decking, and burning infested trees.
KEYW Mountain pine beetle.

140 AUTH Fahnestock, G. R.
DATE 1953
TITL Chipping takes the hazard out of logging slash.
PUBL Research Note 125. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST The effectiveness of chipping on the inflammability of logging slash was tested in an experimental burning program at Priest River Experimental Forest, ID, in 1952. A portable chipper mounted on a two-wheel trailer was used. Green slash put through the machine and allowed to dry for over 2 months could scarcely be burned. Fire behavior in the chipped slash closely resembled that in natural litter and duff. Species appeared to be the strongest factor affecting rate of spread. The pines produced the hottest, fastest fires.
KEYW Chipping slash, inflammability of logging slash.

141 AUTH Fahnestock, G. R.
DATE 1953
TITL Inflammability of the current year's logging slash.
PUBL Research Note 124. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 10 p.
ABST Results of the study appeared not to be in accord with the commonly held opinion, based on experience, that certain species of slash produce a much more serious fire hazard than others. Western redcedar was most frequently listed as the most dangerous species from the slash standpoint. During the 1952 experimental burning program, however, cedar exhibited no particularly explosive characteristics and was really below average in rate of spread. Western white pine exhibited the most violent burning activity. Observers formed the impression that fires spread fastest in white pine slash, but analysis failed to demonstrate any significant difference due to species. Even hemlock proved to be as inflammable as cedar, pound for pound, when present in sufficient quantity to offset the absence of needles.
KEYW Inflammability of logging slash.

142 AUTH Fahnestock, G. R.
DATE 1953
TITL Relative humidity and fire behavior in logging slash.
PUBL Research Note 126. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Plots containing different amounts of slash per acre were burned when relative humidity was increasing rapidly. Comparison of rate of spread with current relative humidity showed that high humidities greatly reduced rate of spread in light and medium slash concentrations but had no significant effect on fires in heavy concentration. Average rate of spread is given by species tested, including western white pine.
KEYW Fire behavior.

143 AUTH Fahnestock, G. R., Dieterich, J. H.
DATE 1962
TITL Logging slash flammability after 5 years.
PUBL Research Paper INT-70. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 15 p.
ABST During the 5 years after it was cut and placed on sample plots, slash of nine Northern Rocky Mountain tree species changed greatly in appearance and flammability. Western white pine, lodgepole pine, western redcedar, and western hemlock still retained relatively large amounts of fine slash components well above the ground; experimental burning showed that flammability was still high. Grand fir and western larch had deteriorated most, and they exhibited very low flammability. Douglas-fir, ponderosa pine, and Engelmann spruce were intermediate.
KEYW Slash, flammability of logging slash, fire spread.

144 AUTH Faller, A., Jackson, M. T.
DATE 1968
TITL Vegetation gradients on Wizard Island, a volcanic cinder cone in Crater Lake, Oregon.
PUBL In: Proceedings Indiana Academy of Science. 77: 183. Abstract.
ABST Wizard Island, which covers about one-half square mile, is a volcanic cone extending about 760 feet above the present level of

Crater Lake. Eighty species of vascular plants are known to occur on the island, including 17 new species reported in this study. Forest associations include a rather dense *Tsuga mertensiana-Abies magnifica* var. *shastensis-Pinus monticola* forest which encircles the base of the cone.
KEYW Vegetation gradients, Crater Lake, Oregon, vegetation distribution, forest associations.

145 AUTH Farquhar, H. H.
DATE 1912
TITL Seed collection on a large scale.
PUBL In: Yearbook of Agriculture; Washington, DC: U.S. Department of Agriculture. p. 435-442.
ABST This article emphasized the need for large quantities of forest seed to replenish burned-over or cutover areas. A large seed collecting campaign for western white pine on the Kaniksu National Forest, ID, was described.
KEYW Seed collection, cone crop prediction, reforestation.

146 AUTH Fellin, D. G., Kennedy, P. C.
DATE 1972
TITL Abundance of arthropods inhabiting duff and soil after prescribed burning of forest clearcuts in northern Idaho.
PUBL Research Note INT-162. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST Abundance of some arthropods inhabiting the duff and soil on three clearcut areas that were prescribed burned was investigated in north-central Idaho. Generally more arthropods were present and more taxa were represented on older burns. In duff samples, the Acarina, Chilopoda, Thysanoptera, Protura, and Thysanuara were most numerous in more recent burns. Acarina comprised 77 percent of the fauna in the duff samples. Soil samples collected before mid-July contained about 90 percent of the total number of individuals—mostly immatures—especially on the oldest burn. The most abundant arthropod in the soil samples on the oldest burn was the carabid *Amara arratica*. Because of the abundance of this carabid and its seed-eating behavior, it is recommended that direct seeding of western white pine, and perhaps of other conifers, be done the first or second season after prescribed burning.
KEYW Arthropods, duff, soil, prescribed burning, direct seeding, *Amara arratica,* Carabidae.

147 AUTH Ferre, Y. D.
DATE 1962
TITL Brachyblastes a normaux chez *Pinus monticola.*
PUBL Bulletin of the Society of Natural History of Toulouse. 97: 373-388.
ABST Describes a batch of seedlings in which the normal 5-needle fascicles were rare, 4- or 10-needle fascicles occurred occasionally, and 6-, 7-, 8-, or 9-needle fascicles often.
KEYW Brachyblastes, short shoot.

148 AUTH Ferrell, W. K.
DATE 1955
TITL The relationship of pole blight of western white pine to edaphic and other site factors.
PUBL Research Note 13. Moscow, ID: University of Idaho, Forestry Wildlife and Range Experiment Station. 7 p.
ABST The aim of this study was to determine the range of topographic and edaphic conditions over which pole blight might occur and to compare it with the range of conditions in healthy pole stands of western white pine. While some soils or sites may be more conducive to the pole blight condition than others, the hypothesis that soil or site characteristics may directly cause this condition is not substantiated.
KEYW Pole blight, soils.

149 AUTH Ferrell, W. K., Hubert, E. E.
DATE 1952
TITL The use of radioisotopes in forest tree research.
PUBL Idaho Forester. 34: 42-45.
ABST This article is a synopsis of the current (1952) uses being made of radioisotopes in forest research. Three different types of tracer studies involving pole-blighted western white pine are presented as examples.
KEYW Radioisotopes, tracer studies, mycorrhizal fungi, pole blight.

150 AUTH Ferrell, W. K., Johnson, F. D.
DATE 1954
TITL A study of the absorption and translocation of mineral elements in diseased and healthy western white pines by the use of radioactive materials.
PUBL Progress Report, Atomic Energy Commission Contract No. AT (45-1)-373. 28 p.
ABST Distribution patterns for Ca and P were determined using radioisotopes of these two elements. The patterns of accumulation were compared among healthy western white pine, pole-blighted trees, and trees infected with *Armillaria mellea* or *Fomes pini.* Seedlings, pole-sized, and large trees were studied. Accumulation data are pictured graphically.

KEYW Radioisotope translocation, pole blight, *Armillaria mellea, Fomes pini.*

151 AUTH Ferrell, W. K., Johnson, F. D.
DATE 1956
TITL Mobility of Calcium-45 after infection in western white pine.
PUBL Science. 124: 364-365.
ABST Calcium-45 was used to study the mobility of calcium in western white pine. Results indicate there was a substantial movement of previously deposited calcium into newly developed buds.
KEYW Calcium-45, translocation.

152 AUTH Ferrell, W. K., Johnson, F. D., Michelsen, C. E.
DATE 1960
TITL Movement and distribution of radiophosphorus in crowns of healthy and pole-blighted western white pines (***Pinus monticola*** D. Don.)
PUBL Plant Physiology. 35: 413-417.
ABST Field experiments were performed to determine the distribution of phosphorus 32 after injection into pole-sized trees in healthy and in pole-blighted condition. On the basis of activity per gram of leaf tissue, accumulations were largest in the upper crowns of the healthy trees and in the lower crowns of the pole-blighted trees. Calculations on a specific activity basis gave no significant difference from the calculations of activity per gram of leaf tissue. Taking the tree as a whole, the rate of phosphorus 32 movement was considerably faster in the pole-blighted than in the healthy trees. When the extreme tops were severed, however, the rate in the severed tops was more rapid in the healthy than in the pole-blighted trees.
KEYW Radioisotopes, pole blight, translocation, radio-phosphorus.

153 AUTH Ferrell, W. K., Olson, D. S.
DATE 1952
TITL Preliminary studies on the effect of fire on forest soils in the western white pine region of Idaho.
PUBL Research Note 4. Moscow, ID: University of Idaho, Forestry Wildlife and Range Experiment Station. 7 p.
ABST The organic layer is shallow in western white pine forests because equilibrium between the rates of annual needle cast and decomposition is reached at a relatively early stage. Even so, when fires overrun the forest floor a large volume of organic matter with some plant nutrients is destroyed. In the majority of cases studied burning had little effect on the rate of water entry into the soil. Significant erosion was found on only one area studied; this was the development of 1/8-inch to 3/16-inch pedestals from rain drop action on a severely burned site. Chemical analyses of the soil samples showed pH values consistently higher on the burned than the unburned soils. Nitrogen percentages were higher on burned soils in six cases and lower in three. Available phosphorus was higher in five cases on burned soils and lower in three.
KEYW Soils, fire soils.

154 AUTH Filler, M. C., Hofstrand, A. D., Howe, J. P.
DATE 1964
TITL Laminated beam design for four western softwoods.
PUBL Forest Products Journal. 14: 451-455.
ABST Based on theoretical calculations and tests of a limited number of laminated beams, it appeared that recommended design stresses could be justified using a proportion of low-grade boards in the beams. Values of modulus of elasticity were higher than established values for the species tested. The difference in average moduli of elasticity between scarfed and nonscarfed latch beams was not significant. Scarfed beams appeared to have a lower moduli of rupture than nonscarfed beams. However, strength of scarfed beams when converted to working stresses was above fiber stress design limits.
KEYW Laminated beams, static bending tests.

155 AUTH Finch, T. L.
DATE 1948
TITL Effect of bark growth in measurement of periodic growth of individual trees.
PUBL Research Note 60. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The formula for western white pine is given as: $a = A - 2.075\,g$, when a = d.b.h. (o.b.) n years ago; A = current d.b.h. (o.b.); g = n years radial growth, not including bark. The equation was based on 126 western white pine trees.
KEYW Bark growth.

156 AUTH Fisher, G. M.
DATE 1935
TITL Comparative germination of tree species on various kinds of surface-soil material in the western white pine type.
PUBL Ecology. 16: 606-611.
ABST Standard greenhouse tests were made with all the principal tree species of the western white pine type on surface-soil materials typical for the area. The results show only the comparative germination of each species

tested on the kinds of soil material used. Data are given for germination percentages within 100 days of seed sown, by surface-soil material and species, and viability of seed cut, by species; surface-soil materials most and least favorable to germination, germination percentages within 100 days for these materials, and viability percentages, by species; ratings of surface-soil materials as germination media.
KEYW Seed germination.

157 AUTH Fitzgerald, O. A.
DATE 1949
TITL Pole blight kills pines.
PUBL The Spokesman Review. 1949 July 31; Sunday Supplement 8-9.
ABST A newspaper account of the investigations being conducted to determine the causes of pole blight in western white pine.
KEYW Pole blight.

158 AUTH Fitzgerald, O. A.
DATE 1951
TITL Idaho's pole blight clinic.
PUBL American Forests. 57(10): 30-31, 38, 40.
ABST Written for lay readers, this article summarizes current (1951) research and knowledge concerning pole blight.
KEYW Pole blight.

159 AUTH Fitzgerald, O. A.
DATE 1951
TITL Plague in the big pines.
PUBL Popular Mechanics. 95(4): 140-142, 242, 246.
ABST This article, written in a popular style, gives an overall description of the pole blight problem and current research on the disease.
KEYW Pole blight.

160 AUTH Fitzwater, J. A.
DATE 1924
TITL A management plan for the Priest River Working Circle.
PUBL Idaho Forester. 6: 9-11, 62.
ABST Management practices in a working circle within the Kaniksu National Forest are presented. Volume by forest type, age class distribution, fire history, and the causes of fire are given.
KEYW Management, working circle, fire, mountain pine beetle, age class, volume.

161 AUTH Flint, H. R.
DATE 1925
TITL Fire resistance of Northern Rocky Mountain conifers.
PUBL Idaho Forester. 7: 7-10, 41-43.
ABST Inherent characteristics that influence fire resistance are (1) thickness of bark, (2) root habit, (3) resin content of bark, (4) branching habit, (5) stand habit, (6) relative inflammability of foliage, and (7) lichen growth. *Pinus monticola* appears about midway on a chart showing relative fire resistance of important Northern Rocky Mountain conifers.
KEYW Fire resistance.

162 AUTH Fobes, E. W.
DATE 1959
TITL Yield and value of finished lumber from western white pine trees and logs.
PUBL Report FPL-2163. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 32 p.
ABST This report presents data and an analysis of a cooperatively conducted survey of western white pine timber harvested from the Clearwater National Forest in northern Idaho. The 160 trees harvested produced 1,121 logs, 943 of which were sawn. Based on the scale record, only 132 of the trees were one-third or more merchantable. Excluding logs from nonmerchantable trees and cull logs from merchantable trees, 840 logs of merchantable quality were produced.
KEYW Diameter, length, scale results, volume, board-foot volume, grading, size-class, tree breakage.

163 AUTH Foiles, M. W.
DATE 1951
TITL Results of seeding germinated western white pine seed.
PUBL Research Note 95. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Recommended methods of direct-seeding western white pine call for planting in the fall following the control of seed-eating rodents by poisoning. Spring-sowing of germinated seed was tested on four plots as a method of eliminating direct rodent control in order to reduce the cost of direct seeding. This test showed that initial stocking from spot-sown germinated seed was no better than from seed that had been stratified but not germinated. On the other hand, protecting the seed spots from rodents with conical wire screens resulted in significantly greater initial stocking. Therefore, spring-seeding germinated western white pine seed did not eliminate the necessity for rodent control.
KEYW Direct seeding, fall sowing, spring sowing.

164 AUTH Foiles, M. W.
DATE 1951
TITL Test of seeding germinated western white pine seed.
PUBL Tree Planters' Notes. 8: 10-11.

ABST No increase in stocking resulted from sowing germinated seed. Stocking was the same for germinated and ungerminated seeds—46 percent filled spots for both treatments.
KEYW Direct seeding.

65 AUTH Foiles, M. W.
DATE 1955
TITL Thinning from below in a 60-year-old western white pine stand.
PUBL Research Note INT-19. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Results from a test of thinning a 60-year-old western white pine stand indicated that thinning does not appreciably change total volume growth, but it does improve the quality of the final product by increasing diameter growth and improving stand composition.
KEYW Thinning, volume growth, diameter growth, stand composition.

66 AUTH Foiles, M. W.
DATE 1956
TITL Effects of thinning a 55-year-old western white pine stand.
PUBL Journal of Forestry. 54: 130-132.
ABST The thinnings had little effect on total volume production but enhanced the value of the stand by increasing the proportion of high value white pine in it. They stimulated diameter growth of dominant and codominant stems but not at a rate that resulted in an appreciably greater number of larger diameter trees than on the check plot.
KEYW Thinning, volume per acre, diameter growth.

67 AUTH Foiles, M. W.
DATE 1959
TITL Silvics of grand fir.
PUBL Miscellaneous Publication 21. Washington, DC: U.S. Department of Agriculture, Forest Service. 12 p.
ABST The climatic, edaphic, and physiographic requirements of grand fir and associated species (including western white pine) are described.
KEYW Climate, associated species.

68 AUTH Foiles, M. W.
DATE 1961
TITL Effects of thinning seed spots on growth of three conifers in the Inland Empire.
PUBL Journal of Forestry. 59: 501-503.
ABST Direct sowing of ponderosa pine, western white pine, and Engelmann spruce seeds in small prepared spots resulted in establishment of several seedlings in each spot. Some spots were artificially thinned to test the effects of seed-spot density on the growth of each of these species in northern Idaho and northeastern Washington. Results of this experiment show that the number of seedlings per spot significantly affected diameter growth of 17-year-old trees of all three species. Diameter growth of the dominant seedlings decreased as the number of seedlings per spot increased. A decrease in height growth of western white pine on densely stocked spots was significant in one test but not in the other. Thinning seed spots is not recommended, for a satisfactory stand will develop without it.
KEYW Seed spot thinning, direct seeding.

169 AUTH Foiles, M. W.
DATE 1965
TITL Time required to prune crop trees in the western white pine type.
PUBL Research Note INT-32. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST This test was designed to provide estimates of the time required to prune white pine crop trees to a height of 18 feet. The following factors influence labor time: density of stocking and brush cover; number, size, and condition of branches; topography; height of pruning; tree species; crew training, experience, and supervision. Data show that with average stand conditions approximately 37 trees can be pruned per person-day, but that a combination of the factors listed above can reduce the person-day production to as low as 16 trees.
KEYW Pruning.

170 AUTH Foiles, M. W.
DATE 1972
TITL Responses in a western white pine stand to commercial thinning methods.
PUBL Research Note INT-159. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST Effects of crown and selection thinning at two levels (20 percent and 35 percent volume removed) and of no thinning were compared in an 87-year-old mixed conifer stand dominated by western white pine and grand fir. The 35-percent crown thinning produced the best diameter growth response and resulted in least mortality during the 10 years following treatment. Net annual volume growth per acre was highest on the control plots (837 bd ft), but was nearly as

high for light-crown thinning (776 bd ft). Light selection thinning was almost as effective as the crown thinnings, but 35 percent selection thinning resulted in excessive mortality and reduced net volume growth.
KEYW Stand conditions, thinning.

171 AUTH Foote, P. A., Mirov, N. T.
DATE 1933
TITL A phytochemical investigation of the oleoresin of *Pinus monticola* Dougl.
PUBL Journal of the American Pharmacy Association. 22: 825-834.
ABST The oleoresin of *Pinus monticola,* obtained from trees growing under unfavorable conditions in the Warner Mountains of California, has been investigated. The environment of the trees is described. Details of the oleoresin extraction are given, supplemented by tables of yield for oleoresin, oil, and resin. The properties of each are described. The oil contains d-alpha-pinene, 60 percent; beta-pinene, 26 percent; n-undecane, 1-2 percent; and sesquiterpenes. Limonene is perhaps present.
KEYW Oleoresin.

172 AUTH Foster, R. E.
DATE 1957
TITL Pole blight of western white pine.
PUBL Ottawa: Canadian Department of Agriculture, Forest Biology Division, Science Service. 5 p.
ABST This report outlines the history of the disease and investigations carried out by the forest biology laboratory. Data include mortality in the vertical and lateral root systems of western white pine, and progress of pole blight on experimental plots in the Silverton area, BC. The authors recommend that if the percentage of affected pine is sufficient to warrant salvage, all pine of merchantable size, healthy and affected, should be harvested, as a partial cut would fail to provide adequate protection to the residual stand.
KEYW Pole blight, cambial lesions, leader growth, roots, root mortality.

173 AUTH Fowler, M. E.
DATE 1950
TITL Airplane scouting for pole blight of western white pine.
PUBL Journal of Forestry. 48: 23.
ABST Summarizes techniques and methods of an aerial survey for pole blight conducted in 1949 on the St. Joe and Clearwater National Forests. Ground checks were necessary to distinguish pole blight from conditions such as logging injury, sunscald, or unusual retention of old yellowed needles.
KEYW Pole blight, aerial survey.

174 AUTH Fowler, M. E.
DATE 1952
TITL Aircraft scouting for pole blight and oak wilt.
PUBL Journal of Forestry. 50: 191-195.
ABST This article summarizes results of aerial surveys made in 1949, 1950, and 1951.
KEYW Pole blight, aerial survey.

175 AUTH Fowler, M. E.
DATE 1952
TITL Information sought on distribution of white pine pole blight.
PUBL Journal of Forestry. 50: 1.
ABST Requests information on suspected pole blight on the Pacific Coast.
KEYW Pole blight.

176 AUTH Fowler, M. E.
DATE 1954
TITL Pole blight.
PUBL American Forests. 54(20): 48.
ABST Gives the symptoms of the pole blight disease and indicates that aerial surveys can give accurate estimates of the extent of the disease.
KEYW Pole blight, aerial survey.

177 AUTH Franklin, J. F.
DATE 1965
TITL Tentative ecological provinces within the true fir-hemlock forest areas of the Pacific Northwest.
PUBL Research Paper PNW-22. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 31 p.
ABST This paper suggests useful geographic divisions of the true fir-hemlock forests of western Oregon and Washington. Western white pine is listed as a major species in Mount Adams, Mount Hood, Three Sisters, Crater Lake, Wenatchee, and Siskiyou provinces and as a minor species in Mount Baker, Mount Rainier, Willamette, and Olympic provinces.
KEYW Ecological province, western Washington, western Oregon, true fir-hemlock forests.

178 AUTH Franklin, J. F.
DATE 1968
TITL Cone production by upper-slope conifers.
PUBL Research Paper PNW-60. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 21 p.
ABST This paper is a progress report on cone-bearing habits of seven upper-slope tree species in the Pacific Northwest. Nine plots of the 47 were of western white pine. Western white pine was a consistent cone

producer and showed a general pattern of cone periodicity.
KEYW Cone production, cone periodicity, Pacific Northwest.

179 AUTH Franklin, J. F., Carkin, R., Booth, J.
DATE 1974
TITL Seeding habits of upper-slope tree species; (1) a 12-year record of cone production.
PUBL Research Paper PNW-213. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.
ABST A 12-year study of cone production by noble, Pacific silver, grand, white, subalpine, and Shasta red firs, mountain hemlock, western white pine, and Engelmann spruce showed that upper-slope species produce medium to heavy crops at 2- to 3-year intervals at most locations. The 1968 cone crop was the heaviest observed to date.
KEYW Cone counting, cone production, cone crop intervals.

180 AUTH Franklin, J. F., Dyrness, C. T.
DATE 1973
TITL Natural vegetation of Oregon and Washington.
PUBL General Technical Report PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 417 p.
ABST Descriptions of each vegetation zone include composition and succession as well as discussion of variations associated with environmental gradients.
KEYW Vegetation, plant communities, habitat types, plant succession, soils.

181 AUTH Franklin, J. F., Hoffman, J.
DATE 1968
TITL Two tests of white pine, true fir, and Douglas-fir seed spotting in the Cascade range.
PUBL Research Note PNW-80. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 11 p.
ABST Satisfactory stocking was obtained on seed spots protected from rodents by wire screens but generally not on unscreened spots despite extensive baiting of study areas. Western white pine was the most successful species used and true firs were least successful. Damping-off, rodents, and insects were responsible for most seedling mortality.
KEYW Clearcuts, seed germination, survival, direct seeding, rodents.

182 AUTH Funk, A.
DATE 1964
TITL Extensions of the host ranges and distribution of *Caliciopsis* species on western conifers.
PUBL Plant Disease Reporter. 48: 677.
ABST The host ranges of species of *Caliciopsis* that attack conifers growing in western North America were reported in 1963. Through artificial inoculations, *Caliciopsis pinea* was shown to attack western white pine vigorously while inoculations on Douglas-fir were negative. Further observations on host range, occurrence, and pathogenicity are reported here.
KEYW *Caliciopsis pinea*, artificial inoculation.

183 AUTH Furniss, R. L., Carolin, V. M.
DATE 1977
TITL Western forest insects.
PUBL Miscellaneous Publication 1339. Washington, DC: U.S. Department of Agriculture, Forest Service. 603 p.
ABST Biological aspects of western North American Forest insects are described. Contains a diagnostic host index as well as a general index.
KEYW Western insects, insects.

184 AUTH Garrett, P. W.
DATE 1970
TITL Early evidence of weevil resistance in some clones and hybrids of white pine.
PUBL Research Note NE-117. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.
ABST White pine species and hybrids were being tested for inherent resistance to the white pine weevil. First-year results offered hopes of finding or developing resistance in this group. *Pinus monticola* had a low level of weeviling, while the hybrid *P. strobus* x *P. wallichiana* was heavily weeviled.
KEYW *Pissodes strobi,* weevil resistance, clones, hybrids.

185 AUTH Genys, J. B.
DATE 1963
TITL Summary of forest tree improvement work in Maryland by the Natural Resources Institute, University of Maryland.
PUBL Annapolis, MD: University of Maryland, Natural Resources Institute, Mimeograph Report 63-40. 7 p.
ABST In 1962-63, the Natural Resources Institute started an experiment with 156 provenances of white pines. This study included the most densely sampled eastern white pine; 20 seed samples of Himalayan white pine, the majority of which originated in Pakistan, India,

and Bhutan; and 11 provenances of western white pine.
KEYW Provenance test.

186 AUTH Genys, J. B.
DATE 1963
TITL Two-year growth differences in five white pine species, studied in Maryland.
PUBL Annapolis, MD: University of Maryland, Natural Resources Institute, Mimeograph Report 63-52. 4 p.
ABST In 1961 the Natural Resources Institute in cooperation with the Maryland Department of Forests and Parks initiated this research project to learn some facts about the performance of exotic white pines (series *Strobi*) in comparison to eastern white pine. Species involved were *P. strobus*, *P. monticoLa*, *P. griffithii*, *P. lambertiana*, and *P. ayacahuite*. Western white pine and Mexican white pine seedlings had most of the seed coats shed when the seed of Himalayan pine was still in the ground. Western white pine was the first one to form terminal buds in 1962, followed by Mexican white pine and sugar pine. Himalayan white pine continued the seasonal height growth the longest, as well as the southern sources of eastern white pine. Analysis of 2-year height growth showed three significantly different ranks of performance. Mexican white pine and sugar pine seedlings were very significantly larger than other seedlings tested. On the other extreme, two provenances of western white pine from Idaho were very distinctly smaller than others. The smallest seedlings in the experiment originated from a blister-rust-resistant western white pine in Idaho.
KEYW Provenance test.

187 AUTH Genys, J. B.
DATE 1964
TITL Report on establishment of tree seed orchards in Maryland with a special reference to white pines.
PUBL In: Proceedings, 12th northeastern forest tree improvement conference. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. p. 14-15.
ABST Seven provenances of western white pine were compared with provenances of *P. strobus, P. griffithii, P. sylvestris, P. virginiana,* and *P. glauca* as potted seedlings in a greenhouse. The slowest growing provenance of western white pine attained 66 percent of the height of the fastest growing provenance.
KEYW Seed orchards, Maryland, height growth, provenance test.

188 AUTH Genys, J. B.
DATE 1965
TITL Two-year growth differences in five white pine species studied in Maryland.
PUBL Journal of Forestry. 63: 126-128.
ABST Five white pine species (series *Strobi*) were tested in the Maryland Forest Nursery for comparison of performance. Eleven seed lots were sown in four randomized blocks. Two-year seedlings of sugar pine from Oregon, and apparent hybrids from a tree in Rochester, NY, listed as a Mexican white pine, showed significantly superior heights to those of all other species tested. Western white pine from Idaho (two sources) represented the other extreme, being considerably smaller. Five provenances of eastern white pine and two provenances of Himalayan white pine showed intermediate heights. Himalayan white pine germinated late and formed the first-year terminal buds the latest in the season. Western white, sugar, and Mexican white pine showed the opposite behavior.
KEYW Provenance test.

189 AUTH Gerhold, H. D.
DATE 1961
TITL Testing white pines for weevil resistance.
PUBL In: Proceedings, ninth northeastern forestry tree improvement conference; 1961 August 23-25; Syracuse, NY. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. p. 44-53.
ABST In this proposed plan for testing white pines for weevil resistance, *P. monticola* is considered to be one of the more promising sources of weevil resistance.
KEYW *Pissodes strobi*, weevil resistance.

190 AUTH Gibson, A. L.
DATE 1943
TITL Penetrating sprays to control the mountain pine beetle.
PUBL Journal of Economic Entomology. 36(3): 396-398.
ABST Several penetrating oil sprays were tested for effectiveness against the mountain pine beetle in lodgepole and whitebark pines. A mixture of diesel oil and orthodichlorobenzene proved to be the best compromise between low cost and control. Some advantages of penetrating spray use are mentioned.
KEYW *Dendroctonus ponderosae*, penetrating spray.

191 AUTH Gilbertson, R. L., Leaphart, C. D., Johnson, F. D.
DATE 1961

TITL Field identification of roots of conifers in the Inland Empire.
PUBL Forest Science. 7: 352-356.
ABST During the course of investigations of root systems of western white pine and its associated species in the Inland Empire, a key for field identification of the roots of 11 important coniferous species was developed. Species include *Abies grandis, A. lasiocarpa, Larix occidentalis, Picea engelmannii, Pinus albicaulis, P. contorta, P. monticola, P. ponderosa, Pseudotsuga menziesii, Thuja plicata*, and *Tsuga heterophylla*.
KEYW Root identification, root characteristics, field key roots.

AUTH Gill, L. S.
DATE 1948
TITL A preliminary report on mortality of western white pine in the Bear Paw Tract of the Kaniksu National Forest.
PUBL Typed manuscript dated October 8, 1948. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Moscow, ID.
ABST Mortality plots were established in a stand exhibiting mortality to an unclassified disease. Eventually it was identified as pole blight. All dead white pine were tallied by 2-inch diameter class. Mortality in the 10-inch class was about twice that of any other class.
KEYW Pole blight, mortality level.

AUTH Gill, L. S.
DATE 1949
TITL A review of the research and survey work on pole blight of western white pine by the Division of Forest Pathology.
PUBL Northwest Scientific Association Meeting Report; 1949 December 7; Albuquerque, NM. 3 p.
ABST The 1948 work was largely exploratory and not productive of definite conclusions. Studies on the stems and roots of several trees in pole blight areas suggested that a diseased condition of the root system is part of the pole blight complex, and the earliest symptoms of the disease may very well appear in the roots and could easily develop before pole blight is recognized in the crown. Of the organisms known to attack roots of western white pine, *Armillaria mellea* was the one most frequently isolated; the one fungus found to show definitive pathogenic tendencies under laboratory conditions was believed to be *Scopularia serpens.* A 100 percent tally on a 44-acre tract plot in the Bear Paw drainage of the Kaniksu National Forest showed that in 8 years, 10 percent of the merchantable trees had died from pole blight.
KEYW Pole blight, *Armillaria mellea.*

194 AUTH Gill, L. S., Andrews, S. R.
DATE 1949
TITL Note on a *Scopularia* attacking western white pine.
PUBL Plant Disease Reporter. 33: 227.
ABST While engaged in investigations of "pole blight," a disease of unknown cause, attacking western white pine in Idaho, Montana, and Washington, the writers had occasion to make several hundred isolations in an attempt to determine what fungi, if any, were involved. Among the fungi isolated were several members of the genus *Scopularia preussemend (Leptographium).* One of them resembled *S. serpens* more strongly than it did any species previously reported on western white pine from this region and was particularly noteworthy because preliminary tests indicate it may be parasitic on bark as well as wood. The fungus was isolated from stems and roots of diseased as well as apparently healthy trees at several widely scattered points throughout the range of *Pinus monticola.* Several isolates were used for inoculations in short pieces of pine stems on which they produced definite bark lesions in 5 to 8 days and often caused blue stain in the underlying wood within 3 weeks.
KEYW *Scopularia,* pole blight.

195 AUTH Gill, L. S., Andrews, S. R., Millenbaugh, R. E.
DATE 1949
TITL Pole blight investigations by Forest Pathology, 1948.
PUBL Unpublished Report 141. Albuquerque, NM: U.S. Department of Agriculture, Bureau of Plant Industry, Division of Forest Pathology. 22 p.
ABST This review of the work on pole blight for 1948 includes surveys, maps of pole blight locations, patterns of bark necrosis, tree descriptions, root system analyses, presence of root-rotting fungi, artificial inoculations with various isolates, damage studies, virus tests.
KEYW *Scopularia, Armillaria mellea, Cryptosporium, Atropellis, Cucurbicothis, Stigmella, Endobotryella, Penicillium, Trichoderma*, virus tests, pole blight, pole blight locations.

196 AUTH Gill, L. S., Leaphart, C. D., Andrews, S. R.
DATE 1951
TITL Preliminary results of inoculations with a species of *Leptographium* on western white pine.

PUBL Forest Pathology Special Release 35. Albuquerque, NM: U.S. Department of Agriculture, Bureau of Plant Industry, Division of Forest Pathology. 14 p.
ABST Preliminary inoculation tests indicated that a fungus similar to *Leptographium serpens* may be involved in the pole blight disease of western white pine. In 1949, inoculations of this and three other fungi (*Armillaria mellea, Scopularia,* and *Poria weirii*) were attempted in seven plots. Field examinations of the inoculations made during the summer of 1950 showed that, while no crown symptoms of pole blight were present on any of the plots, many of the *Leptographium* stem inoculations had resulted in heavy resinosis. Inspections of the root inoculations showed that *Leptographium* sp. was also active in most cases, whereas those made with the other fungi appeared to be negative.
KEYW Pole blight, *Leptographium, Scopularia, Armillaria mellea, Poria weirii,* inoculation.

197 AUTH Graham, D. P.
DATE 1955
TITL Distribution of pole blight of western white pine.
PUBL Research Note INT-15. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Disease surveys conducted in 1953 and 1954 to determine the distribution of pole blight of western white pine revealed that most areas of damage had been found. The established range of the disease had not increased in the past 2 years except for some extension to the northeast on the Coeur d'Alene National Forest and the extensions east and northwest on the St. Joe National Forest. The acreage of western white pine affected by pole blight in the United States was estimated to be between 90,000 and 95,000 acres of moderate to severe damage.
KEYW Pole blight, disease survey.

198 AUTH Graham, D. P.
DATE 1958
TITL Results of pole blight damage surveys in the western white pine type.
PUBL Journal of Forestry. 56: 652-655.
ABST A sample-plot survey to determine the damage caused by the pole blight disease and its effect on the stand was made in the western white pine type. Stands sampled were distributed throughout the known range of the disease. Results of this survey confirmed that pole blight is a serious problem in the western white pine type. The past and current level of damage, as determined from the survey, has caused and is continuing to cause (1958) a serious reduction in productivity. Pole blight damage in many affected stands greatly exceeded growth and thus, under current conditions, will eliminate white pine as a commercially important species in these stands in a relatively short time.
KEYW Pole blight, pole blight survey.

199 AUTH Graham, D. P.
DATE 1958
TITL Results of some silvicultural tests in pole blight diseased white pine stands.
PUBL Journal of Forestry. 56(4): 284-287.
ABST Data are presented from two studies on the effects of cutting on pole blight of western white pine. Preliminary results indicated that thinning subsequent to the appearance of the disease and salvage cutting of affected areas does not reduce disease progress in the residual stand.
KEYW Pole blight, basal area, thinning, salvage cut, residual stand.

200 AUTH Graham, D. P.
DATE 1959
TITL Pole blight threatens western white pine.
PUBL Western Conservation Journal. 16: 16-17.
ABST The author indicated that the cause of pole blight was still unknown, but its effects were obvious: it kills pole-sized trees of one of our most valuable commercial tree species. Distribution surveys showed that nearly one-seventh of the acreage in white pine pole-sized stands was affected in 1959 and that about 50 percent of these trees were diseased or dead, representing a yearly loss of about 17 3/4 million cubic feet. Possible causes of pole blight are listed as infectious agents, nutritional deficiencies, soil conditions, and climatic factors. No effective control can be undertaken until the cause is determined.
KEYW Pole blight.

201 AUTH Graham, R. T.
DATE 1980
TITL White pine vigor—a new look.
PUBL Research Paper INT-254. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 15 p.
ABST Vigor classes for mature western white pine were used to estimate periodic annual diameter growth, but no differences in diameter growth rate could be detected between the excellent, good, and fair vigor classes. The diameter growth rate of the poor vigor class was different from the other classes. Using individual tree characteristics (crown ratio, crown class, and tip vigor), no better predic-

tion of diameter growth rate could be achieved.
KEYW Vigor classes, diameter growth, growth and mortality, stand condition, mortality condition.

202 AUTH Graham, R. T., Tonn, J. R.
DATE 1979
TITL Response of grand fir, western hemlock, western white pine, western larch, and Douglas-fir to nitrogen fertilizer in northern Idaho.
PUBL Research Note INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST Significant ($p < 0.05$) responses in diameter growth to fertilization were noted at one of the study areas. Significant differences were detected between the height growth means in both study areas. Differences between the height and diameter growth means for the 200 lb N per acre treatment and the 400 lb N per acre treatment were not significant. When each species was analyzed separately, only grand fir and Douglas-fir had a significant response to fertilizer application.
KEYW Fertilization, diameter growth, height growth.

203 AUTH Graham, R. T., Tonn, J. R.
DATE 1980
TITL Case study: growth and development of forest stands in the Northern Rocky Mountains.
PUBL Research Paper INT-255. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 p.
ABST Tree diameter and height growth were compared for nine habitat types. Ten-year diameter growth was highly variable among habitat types as was 10-year height growth. High variation in both diameter and height growth also occurred within habitat types. Thirty-six local yield tables are presented, one for each stand in the study.
KEYW Growth and habitat types, growth, yield tables.

204 AUTH Graham, R. T., Wellner, C. A., Ward, R.
DATE 1983
TITL Mixed conifers, western white pine, and western redcedar.
PUBL In: Burns, R. M., technical compiler. Silvicultural systems for the major forest types of the United States. Agriculture Handbook 445. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 67-69.
ABST Summarizes the size, climate, habitat, and associated species of cover types western white pine and western redcedar. Production potential, insect and disease problems, and management possibilities are also discussed.
KEYW Cover types, climate, associated species, management methods.

205 AUTH Grand, L. F.
DATE 1968
TITL Conifer associates and mycorrhizal syntheses of some Pacific Northwest *Suillus* species.
PUBL Forest Science. 14: 304-312.
ABST The relative frequency of occurrence of sporophores of various *Suillus* species, as determined in natural stands of certain conifers in northern Idaho, indicated possible mycorrhizal relationships among *S. granulatus*, *S. sibiricus*, and *S. tomentosus* vars. *discolor* and *tomentosus* with *Pinus monticola*, as well as other *Suillus* species with other northern Idaho conifers.
KEYW *Mycorrhiza*, *Suillus granulatus*, *Suillus sibiricus*, *Suillus tomentosus*.

206 AUTH Gravelle, P.
DATE 1977
TITL Growth response and logging damage to advanced regeneration following overstory removal: the present state of knowledge.
PUBL Forest Technical Paper TP-77-3. Lewiston, ID: Potlatch Corporation. 27 p.
ABST A review of current literature is presented on the growth release and damage effects of overstory removal cutting on advanced regeneration. Available information indicated that diameter growth can be expected to increase the first year after release from overstory competition. Height growth response may be delayed for 2 to 5 years, but will then increase 2 to 4 times the rate before overstory removal. Logging may disturb up to 30 percent of an area, but if done with care, will not seriously affect the future management of the advanced regeneration. Decay incidence in stem injuries of young trees should not become a problem if the wounds heal within 10 years. Recommended guidelines are presented to reduce logging damage and choose crop trees in precommercial thinnings following logging.
KEYW Growth response to light levels, logging damage.

207 AUTH Green, A. W., Alley, J. R.
DATE 1967
TITL Evaluating species alternatives for National Forest land capable of growing western white pine.

PUBL Research Paper INT-43. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 40 p.
ABST Economic evaluations of species alternatives for timber production on cutover lands on National Forests are necessary for efficient use of money in achieving basic management goals. The basic biological and economic considerations for such evaluations are discussed and a sample problem is presented. Two EDP investment analysis programs are listed with instructions for use in ranking alternative species and management programs.
KEYW Species alternatives.

208 AUTH Habeck, J. R.
DATE 1968
TITL Forest succession in the Glacier Park cedar-hemlock forests.
PUBL Ecology. 49: 872-880.
ABST A gradient analysis and description was made of forest succession among the *Thuja plicata-Tsuga heterophylla* communities in the vicinity of Lake McDonald in Glacier National Park, MT. Thirty-three pioneer, seral, and climax communities located on well-drained slopes at elevations between 3,200 and 3,500 ft were sampled. Through the calculation of indices of community similarity and dissimilarity, the stands were objectively arranged along a unidimensional gradient. The data summarized along the resulting ordination gradient provide a quantitative description of the basic successional pattern existing among these cedar-hemlock communities. Typically, following burning *Pinus contorta* communities become established, and these in turn are gradually replaced by *Pinus monticola* and *Pseudotsuga menziesii* in various proportions. Climax communities on the upland sites become dominated by *Tsuga heterophylla,* with smaller, but self-reproducing populations of *Thuja plicata* also persisting.
KEYW Forest succession, Glacier Park.

209 AUTH Haig, I. T.
DATE 1924
TITL Accelerated growth after cutting in western white pine.
PUBL District 1 Applied Forestry Note 55. Missoula, MT: U.S. Department of Agriculture, Forest Service. 5 p.
ABST This preliminary study seems to warrant the conclusion that western white pine makes accelerated growth after partial cutting. The response appears to be relatively greater in the smaller trees and those of lower crown class than in the larger trees. Response is markedly less in trees that are slightly lacking in health and vigor. In general, western white pine appears to be much less aggressive in responding to stimulation than western yellow pine. Acceleration begins usually 2 years after cutting and shows no sign of slowing up at 15 years, the oldest area studied.
KEYW Partial cutting, diameter growth, volume crown class.

210 AUTH Haig, I. T.
DATE 1924
TITL The application of normal yield tables.
PUBL Journal of Forestry. 22: 902-906.
ABST Discusses the application of normal yield tables being prepared at Priest River Experimental Forest for the western white pine type. A study is under way to determine a correction factor that will permit application of normal yield tables to actual stands.
KEYW Yield tables, normal yield, correction factor growth.

211 AUTH Haig, I. T.
DATE 1925
TITL The effect of slash disposal on subsequent reproduction.
PUBL District 1 Applied Forestry Note 60. Missoula, MT: U.S. Department of Agriculture, Forest Service. 3 p.
ABST Data for seven species showed that slash left after logging exerts a noticeable influence in reducing the amount of reproduction in the western white pine type. Therefore, slash removal, though primarily a fire protection measure, is an excellent silvicultural measure as well.
KEYW Slash disposal, reproduction, regeneration, seedlings per acre.

212 AUTH Haig, I. T.
DATE 1925
TITL Shortcuts in measuring tree heights.
PUBL Journal of Forestry. 23: 941-944.
ABST The paper describes a simple circular slide rule designed to allow measurement of slope distance and field computation of heights.
KEYW Tree height measurements, slide rule.

213 AUTH Haig, I. T.
DATE 1930
TITL A quarter century of silviculture in the western white pine type.
PUBL Forestry Kaimin. Missoula, MT: University of Montana. p. 36-41, 72-76.
ABST The first National Forest timber sale was made in 1907. Methods for reforestation for white pine were unknown. From 1900 to

1930 methods made a complete circle from seed tree, clearcuts with seed blocks, clearcuts with seed strips, clearcuts with seed groups, back again to scattered seed trees.
KEYW Seed trees windblown, clearcuts, seed trees in blocks, shelterwood cut, clearcut strips, seed storage in duff.

14 AUTH Haig, I. T.
DATE 1931
TITL Stand tables for second-growth western white pine.
PUBL Northwest Science. 5: 94-98.
ABST Contains yield tables for second-growth western white pine, the first ever published. Tables are for fully stocked stands of average composition.
KEYW Stand tables, second growth, diameter class, yield tables.

15 AUTH Haig, I. T.
DATE 1931
TITL The stocked-quadrat method of sampling reproduction stands.
PUBL Journal of Forestry. 29: 747-749.
ABST The stocked-quadrat method is based on the assumption that if a given area is divided into squares of such a size that one established seedling or tree per square will fully stock the square at maturity, then the percentage of units so stocked indicates the proportion of land being utilized by tree growth. A 4-milacre or 3.2-ft^2 unit was adopted for western white pine.
KEYW Stocked-quadrat method, reproduction.

16 AUTH Haig, I. T.
DATE 1932
TITL Comparative timber-yields.
PUBL Journal of Forestry. 30: 575-578.
ABST The author compares the maximum average annual growth of 15 coniferous species. Western white pine ranks ninth in cubic foot growth and fifth in board foot growth. However, it ranks 14th based on relative growth rate based on time for tree to reach 8 inches d.b.h.
KEYW Timber yield, growth rate, maximum annual growth, species comparisons.

17 AUTH Haig, I. T.
DATE 1932
TITL Premature germination of forest tree seed during natural storage in duff.
PUBL Ecology. 13: 311-312.
ABST About one-third of the viable seed stored in the duff germinated during the second season, less than 1 percent the first season.
KEYW Seed germination, seed storage in duff.

218 AUTH Haig, I. T.
DATE 1932
TITL Second-growth yield, stand, and volume tables for the western white pine type.
PUBL Technical Bulletin 323. Washington, DC: U.S. Department of Agriculture, Forest Service. 67 p.
ABST The purpose of this bulletin was to sum up for forest managers and timberland owners the available information on the growth and yield of second-growth western white pine stands. The yield tables give the number of trees, the average size of tree, the rate of growth, and the quantity of wood per acre at different ages and qualities of site for even-aged, fully stocked western white pine stands. The resulting yield tables are applicable to western white pine stands throughout the entire region; they are also applicable to any stand containing 15 percent or more of western white pine.
KEYW Diameter breast height, basal area, age, even aged stands, stocking, composition, dominant, site quality, site index, mean annual increment, periodic annual increment, utilization standards, yield.

219 AUTH Haig, I. T.
DATE 1933
TITL Treatment of understory hemlock in the western white pine type.
PUBL Journal of Forestry. 31: 578-583.
ABST The author recommended the following treatment of hemlock understory stands containing a large percentage of vigorous trees with pointed crowns: (1) Retain the hemlock understory if it is sound. (2) Slash the hemlock understory if it is defective; that is, if over 40 percent of the trees are defective at the time of original logging.
KEYW Understory, stand composition, predicted yield, stumpage value.

220 AUTH Haig, I. T.
DATE 1936
TITL Factors controlling initial establishment of western white pine and associated species.
PUBL Bulletin 41. New Haven, CT: Yale University. School of Forestry. 149 p.
ABST Seedling losses were studied by means of small sown plots scattered over the habitat areas, the surface layers of which were of natural mineral soil, burnt mineral soil, and duff. Conclusions: the direct agents are rodents, soil fungi, soil insects (cutworms), surface soil temperature and soil moisture. Damping off is the most important biotic factor and insolation and drought the most important physical factors. Light is not a direct factor in initial mortality.

KEYW Seedling mortality, root penetration, insolation.

221 AUTH Haig, I. T.
DATE 1939
TITL Accuracy of quadrat sampling in studying forest reproduction on cut-over areas.
PUBL Ecology. 10: 374-381.
ABST This paper discusses the accuracy of quadrat sampling as applied to reproduction studies in the western white pine type, and discusses methods by which this accuracy can be measured. In general, the methods used in this study consisted of counting reproduction on milacre (6.6-ft^2) quadrats distributed at $^1/_2$- or 1-chain (33- or 66-ft) intervals along parallel strips 2.5 to 10 chains apart. This quadrat-at-interval system, giving a sample of from 0.1 to 0.8 percent of total area, was found to give satisfactory values for both frequency index (percentage of area stocked) and average number of seedlings per acre. In checking the values for average number of seedlings per acre, a method is suggested by which the j-shaped frequency distributions, probably common in similar ecological and silvical studies, can be converted into more nearly normal distributions and so strengthened as to permit the application of the probable error concept with a reasonable degree of safety. Indications are given that in sampling by the quadrat-at-interval method it is essential to have the parallel strips well distributed over the area, and that when only a limited sample can be taken, the tendency should be to lengthen the interval between quadrats rather than the distance between strips.
KEYW Quadrat sampling, reproduction, reforestation.

222 AUTH Haig, I. T., Davis, K. P., Weidman, R. H.
DATE 1941
TITL Natural regeneration in the western white pine type.
PUBL Technical Bulletin 767. Washington, DC: U.S. Department of Agriculture, Forest Service. 99 p.
ABST This bulletin brings together the available information on natural regeneration of the western white pine type, based on about 25 years of forest research and 30 years of National Forest timber cutting experience. Information included: geographic distribution of western white pine; history of early investigations and practices; species composition of timber stands; age distribution of different species; climatic factors affecting regeneration including precipitation, snowfall, growing season, temperature; susceptibility to injury including relative fire resistance of individual species, disease considerations (white pine blister rust and other forest tree diseases), insects, snow, and wind; seed supply, including effect of fire on seed maturation, kind and number of seed trees needed, and seed production of associated species; dissemination including distance, storage, losses, source of seed; germination; seedling establishment including losses due to biotic (fungi, insects, birds) and physical agents (insolation, drought); early development including effects of burned-over surfaces, overwood density, and relative aggressiveness of species; regeneration methods including clearcutting, seed tree, shelterwood, and selection. The authors conclude that, according to present (1941) knowledge, the clearcutting, seed tree, and shelterwood methods all deserve a place in the management of the western white pine type because forest conditions are too diverse for any one method to suffice.
KEYW Stand composition, regeneration, precipitation, temperature, fire damage, disease survey, insects, mortality, windthrow, cone crops, seed maturity, seed trees, seed storage, seed germination, seedling establishment, seedling mortality, overwood density, species aggressiveness, shelterwood cut, selection cutting.

223 AUTH Hamilton, D. A., Jr.
DATE 1974
TITL Event probabilities estimated by regression.
PUBL Research Paper INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 18 p.
ABST Describes a computer algorithm for fitting the relation between a dependent variable with only two possible values (for example, individual tree mortality) and a number of independent variables, and procedures for analyzing data from samples with unequal probability. Examples are given of the application of these programs, including estimation of the probability of individual tree mortality in sample plots of western white pine and investigation of natural inactivation of western white pine blister rust.
KEYW Statistical methods, stand characteristics, mortality, survival, decay in trees, assessment, fungus diseases, resistance.

224 AUTH Hamilton, D. A., Jr.
DATE 1981
TITL Large-scale color aerial photography as a tool in sampling for mortality rates.
PUBL Research Paper INT-269. Ogden, UT: U.S. Department of Agriculture, Forest Service,

Intermountain Forest and Range Experiment Station. 8 p.
ABST Lack of knowledge of mortality rates is primarily due to a lack of suitable data and inappropriate or inefficient data collection procedures. Test results indicate that 1-year mortality can be dated and that, with acceptable accuracy, species can be assigned to green trees and to 1-year mortality trees on 1:1600 and 1:2400 scale color aerial photography. These results have led to the design of a mortality sampling procedure that uses a $^{1}/_{2}$-mile strip (8 frames) of 70-mm true color aerial photography at a scale of 1:2400. Each frame covers 2.25 times the area covered by a frame at 1:1600. Use of this larger sample unit increases the likelihood of including some mortality on each sample unit.
KEYW Mortality rates.

225 AUTH Hanley, D. P.
DATE 1976
TITL Tree biomass and productivity estimated for three habitat types of northern Idaho.
PUBL Bulletin 14. Moscow, ID: University of Idaho, Forestry, Wildlife, and Range Experiment Station. 15 p.
ABST Biomass and productivity of coniferous trees of three habitat types in northern Idaho were determined by empirical formulas.
KEYW Habitat types, productivity estimates.

226 AUTH Hanover, J. W.
DATE 1962
TITL Clonal variation in western white pine. I. Graftability.
PUBL Research Note INT-101. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Periodic observations on ramets of thirteen western white pine clones show that individual trees vary in graftability. The type or degree of stock-scion incompatibility leading to poor grafting results also varies and may appear soon after grafting or years later. Detection of long-term incompatibility is not now possible. Survival of ramets appears to be related to vigor of ortets.
KEYW Scion mortality, scion growth, clonal variation, graftability, incompatibility.

227 AUTH Hanover, J. W.
DATE 1965
TITL Effect of the chemical mutagen ethyl methanesulfonate on western white pine.
PUBL Silvae Genetica. 14: 23-26.
ABST The chemical mutagen ethyl methanesulfonate (EMS) was applied in three different concentration-time combinations to control-pollinated western white pine seed after stratification. Eight progenies, including two from self-pollination, were compared for response to the treatments. EMS significantly affected percentage of germination. Time of germination, time of cotyledons, and cotyledon length were not affected. Variations in percentage of germination, germination time, and time of cotyledon opening indicated that individual progenies responded differentially to treatment. Self-pollinated progenies appeared less prone than outcrossed progenies to physiological damage by the mutagen. Examination of the second year's growth on all seedlings revealed one plant with stomatic mutations. These included yellow and green striped needles, yellow needles, dwarfed needles, and variation in number of needles per fascicle sheath.
KEYW Mutagen, mutations.

228 AUTH Hanover, J. W.
DATE 1966
TITL Environmental variation in the monoterpenes of *Pinus monticola* Dougl.
PUBL Phytochemistry. 5: 713-717.
ABST The concentrations of five monoterpenes in western white pine cortex oleoresin were measured by gas-liquid chromatography to determine how they vary with respect to certain environmental factors. Position on the tree relative to the sun and small differences in tissue age are both shown to have a predictable but small effect on terpene levels relative to genetic effects. Large differences in the age of tissues sampled within a single tree result in strikingly different patterns of terpene composition. The repeatabilities or intraclass correlations of monoterpene concentrations in western white pine are high. Genotypically identical plants (clones) growing in three diverse environments in Idaho show negligible differences in monoterpene levels, indicating that monoterpene concentration is quite stable with respect to many environmental factors. The data show that oleoresin from young, foliage-bearing tissue probably gives the most accurate measure of genotypic values for terpene concentrations.
KEYW Monoterpenes.

229 AUTH Hanover, J. W.
DATE 1966
TITL Genetics of terpenes. I. Gene control of monoterpene levels in *Pinus monticola* Dougl.
PUBL Heredity. 21: 73-84.
ABST Alpha-pinene, camphene, beta-pinene, 3-carene, limonene, one unidentified terpene, and total terpene content of cortex oleoresin

in clones, f_1 hybrids, and S_1 progeny of *Pinus monticola* were quantitatively analyzed using gas-liquid chromatography. The level of each monoterpene in a standard volume of oleoresin was shown to be significantly associated with genotype. The inheritance of each terpene except camphene is additive and also appears to include some heterotic or epistatic effects. Growth rate of the plants is negatively correlated with alpha-pinene and total terpenes ($p < 0.01$). Other significant negative correlations exist between beta-pinene and 3-carene, 3-carene and limonene, and limonene and the unidentified terpene. Positive correlations appear between alpha-pinene and limonene and between 3-carene and the unknown. The results indicate that some of the many possible molecular rearrangements in the terpenoids are under fairly rigid genetic regulation.

KEYW Monoterpenes.

230 AUTH Hanover, J. W.

DATE 1966

TITL Inheritance of 3-carene concentration in *Pinus monticola*.

PUBL Forest Science. 12: 447-450.

ABST Concentration of the monoterpene 3-carene in cortex oleoresin of *Pinus monticola* appears to be controlled primarily by single dominant and recessive alleles at a locus designated c/c. Some trees completely lack 3-carene, which indicates that an inhibitor may determine the presence or absence of this monoterpene in white pine.

KEYW Monoterpenes.

231 AUTH Hanover, J. W.

DATE 1971

TITL Genetics of terpenes. II. Genetic variances and interrelationships of monoterpene concentrations in *Pinus monticola*.

PUBL Heredity. 27: 237-245.

ABST Analyses of the monoterpene compounds in western white pine parents and progeny from a factorial mating design show that these chemicals are under strong, predictable genetic control probably involving one to several loci. One compound, beta-pinene, consistently occurs in substantially larger concentrations in progeny than in parents, which suggests an age effect of possible physiological significance. A strong positive relationship exists between the concentrations of 3-carene and terpinolene. Two other pairs of monoterpenes, alpha-pinene and beta-pinene and myrcene and 3-carene are negatively correlated. Except for these interrelationships, the compounds appear to be independently inherited. Negative correlations predominate between mono-terpene concentrations and mean progeny height growth rate. Further work is needed to determine the biological basis, if any, for this relationship.

KEYW Monoterpenes.

232 AUTH Hanover, J. W.

DATE 1974

TITL Comparative physiology of *Pinus strobus* L. and *Pinus monticola* Dougl.: oleoresin composition and viscosity.

PUBL American Journal of Botany. 61: 33.

ABST Eastern white pine and western white pine are two closely related but geographically separated species. Measurements of their foliage and stem cortex oleoresin chemistry and viscosity were made to determine the degree of genetic differentiation that has occurred between the two species for these characteristics. Significant quantitative differences in the monoterpenes camphene, b-pinene, limonene, and total monoterpenes were found. Thirteen diterpene resin acids were detected and all but one differed significantly in concentration between the species. Eastern white pine is characterized especially by having lower pimaric, isopimeric, and abietic acids and higher sandaracopimaric, dehydroabietic + strobic, and neoabietic acids than western white pine. The viscosity of eastern white pine oleoresin samples ranged from 9.2 to 160.6 poises with a mean of 44.0 poises. Western white pine viscosity ranged from 7.9 to 65.9 with a mean of 20.6 poises which differs from eastern white pine at the 0.001 level of probability. Thus the two species have qualitatively similar but quantitatively distinct oleoresin characteristics which may prove useful in interpreting their differential susceptibilities to certain insect and disease pests.

KEYW Physiology, oleoresin.

233 AUTH Hanover, J. W.

DATE 1975

TITL Comparative physiology of eastern and western white pines: oleoresin composition and viscosity.

PUBL Forest Science. 21: 214-221.

ABST Eastern white pine and western white pine are closely related but geographically separated species. Their foliage and stem cortex oleoresin chemistry and viscosity were measured to determine degree of genetic differentiation. From measurements of 40 seedlings of each species, significant quantitative differences in the monoterpenes caphene, ß-pinene, limonene, and total monoterpenes were found. Thirteen diter-

pene resin acids were detected and concentrations of all but one differed significantly between the species. Eastern white pine is characterized especially by lower pimaric, isopimaric, and abietic acids and higher sandaracopimaric, dehydroabietic + strobic, and neoabietic acids. Viscosity of eastern white pine oleoresin ranged from 9.2 to 160.6 poises with a mean of 44.0 poises; western white pine, from 7.9 to 65.9 with a mean of 20.6 poises, which differs significantly from eastern white pine. The two species have qualitatively similar but quantitatively distinct oleoresin characteristics which may prove useful in interpreting their differential susceptibilities to certain insects and diseases.
KEYW Monoterpenes, resin acids, genetic variation, physiology, oleoresin, viscosity.

34 AUTH Hanover, J. W., Barnes, B. V.
DATE 1962
TITL Heritability of height growth in year-old western white pine.
PUBL In: Proceedings, SAF southern forest tree improvement committee meeting forest genetics workshop; 1962 October; Macon, GA. p. 1-6.
ABST An analysis for computing heritability based on a modified diallel cross is described in detail using total height and epicotyl length of 1-year-old *Pinus monticola* seedlings. The data are used to analyze components of variance and obtain estimates of narrow-sense heritability for both growth traits. Epicotyl length is the more reliable measure of heritability, since seed weight and other nongenetic factors have less effect on this character. Results demonstrate the presence of a relatively high male-female interaction in height growth compared with variation due to additive gene action. Some implications of the results with regard to seed orchards are discussed.
KEYW Height growth, heritability growth.

35 AUTH Hanover, J. W., Barnes, B. V.
DATE 1969
TITL Heritability of height growth in western white pine seedlings.
PUBL Silvae Genetica. 18: 80-82.
ABST The inheritance of height growth of 1- and 2-year-old western white pine nursery seedlings was studied using a factorial design similar to the standard North Carolina design II. Variation in 1- and 2-year heights due to additive gene effects was estimated to account for 15.3 and 21.8 percent, respectively, of total variation based upon male parent variance; 52.4 and 50.0 percent based upon female parent variance; and 33.9 and 35.9 percent based upon the combined parental variances. Individual-tree variation within progenies was the major source of variability in height growth. For the improvement of western white pine, as many parents as possible, chosen at random from a natural population, should be used in heritability estimates. There is also need for new measures of progeny performance over reasonable ranges of site conditions.
KEYW Heritability growth, seedling growth.

236 AUTH Hanover, J. W., Hoff, R. J.
DATE 1966
TITL A comparison of phenolic constituents of *Pinus monticola* resistant and susceptible to *Cronartium ribicola*.
PUBL Plant Physiology. 19: 554-562.
ABST Polyphenols and simple phenols in *Pinus monticola* foliage and bark were studied in relation to host resistance to *Cronartium ribicola*. More than 50 phenolic substances were detected, but no qualitative differences were found between resistant and susceptible trees. Some evidence is given for a quantitative relationship between one polyphenol in white pine foliage and resistance to blister rust. This compound may be a guaiacyl derivative. Differences in phenolics due to tree-to-tree variation, needle age, tissue (foliage versus bark), and season of year are also reported.
KEYW Phenols, *Cronartium ribicola*.

237 AUTH Hanover, J. W., Hoff, R. J.
DATE 1966
TITL Pollination of western white pine with water suspensions of pollen—a technique for chemical mutagen treatments.
PUBL Forest Science. 12: 372-373.
ABST Pollen of western white pine was treated with water and the chemical mutagen ethyl methanesulfonate prior to wet pollination to test the effects of such treatments on seed set. Sound seed yield was below normal, but aqueous and chemical treatments of pollen and wet pollination are shown to be feasible.
KEYW Pollination mutagen.

238 AUTH Hansen, H. P.
DATE 1941
TITL Further pollen studies of post Pleistocene bogs in the Puget Sound lowland of Washington.
PUBL Bulletin of the Torrey Botanical Club. 68(3): 133-148.
ABST Pollen studies of two post-Pleistocene bogs showed past glacial forest succession patterns similar to those witnessed in other areas of the Puget lowland. Pioneer forests of lodgepole and western white pine were replaced abruptly by Douglas-fir. Western hemlock eventually takes its place in the

climax forest. The role of past climate trends in forest succession is discussed.
KEYW Pleistocene, bogs, pollen profiles, forest succession.

239 AUTH Hansen, H. P.
DATE 1943
TITL Post-Pleistocene forest succession in northern Idaho.
PUBL American Midland Naturalist. 30: 796-802.
ABST Pollen profile studies of a northern Idaho peat bog showed lodgepole pine to be the major pioneer tree species in post-Pleistocene forest succession. Western white pine gradually superceded it early in the profile and remained predominant throughout. The marked increase of western larch in a couple of western places indicates two periods of recurring fires. These fires are blamed for the lack of development of a climax forest in the profiles.
KEYW Post-Pleistocene forest succession, bog, pollen profiles, pioneer species, climax forest.

240 AUTH Hansen, H. P., Mackin, J. H.
DATE 1940
TITL A further study of interglacial peat from Washington.
PUBL Bulletin of the Torrey Botanical Club. 67: 131-142.
ABST Geological and stratigraphical relationships indicate the peat was deposited during the early part of the Puyallup Interglacial stage. Pollen analysis gives further insights into climatic trends and forest succession.
KEYW Interglacial peat, bog, pollen spectra, forest succession, climate, stratigraphic sequence.

241 AUTH Harlow, W. M.
DATE 1935
TITL *Pinus monticola* D. Don.
PUBL In: Dendrology of important trees of the United States. Part II - softwoods. Ann Arbor: Edward Brothers, Inc. p. 8.
ABST Gives a short description of western white pine's characteristics, range, and importance.
KEYW Dendrology, fruit, bark, leaves, wood, range, reproduction.

242 AUTH Harman, D. M., Brown, M. L.
DATE 1974
TITL Leader and bark characteristics in different growth categories of white pine (*Pinus strobus* L. and *Pinus monticola* Doug.) in Maryland.
PUBL Chesapeake Science. 15: 30-38.
ABST Dimensional and chemical aspects of leaders and bark were investigated in tall (40-75 ft) eastern white pine and in smaller (12-25 ft) trees growing in the open and shade. Leaders from young open-grown trees were longer, of greater diameter, and had thicker bark than leaders from tall white pine and from young shaded white pine. Tall trees were intermediate between the open-grown and shaded trees in leader length and diameter but had the thinnest bark. Bark thickness in similar-aged portions of laterals increased progressively at higher vertical levels in the trees. In spectrophotometer tests, light transmittance was higher for shoots than for bark from lateral branches and the main stem in both eastern white pine and western white pine.
KEYW Leader characteristics, bark characteristics, light transmittance.

243 AUTH Harris, J. M., Kripas, S.
DATE 1959
TITL Notes on the physical properties of ponderosa pine, monticola pine, western redcedar, and Lawson cypress grown in New Zealand.
PUBL New Zealand Forestry Research Note 16. 25 p.
ABST Although it was too early to make predictions of the quality of mature timber which may be produced by *P. monticola* grown in New Zealand, the physical properties of the timber examined from a 24-year-old stand were in many respects similar to those of the timber grown in the United States. This timber should be of value for uses requiring a wood of moderately low density with good machining qualities, light color, and good nailing properties, and which, according to American reports, "stays in place" when properly seasoned. The species also forms heartwood at an early age.
KEYW Physical properties, New Zealand, wood density, shrinkage.

244 AUTH Hartley, C., Merrill, T. C., Rhoads, A. S.
DATE 1918
TITL Seedling diseases of conifers.
PUBL Agricultural Research. 15: 521-559.
ABST Presents an extensive discussion of damping-off in conifer seedlings. Lists fungi known to be involved with some indication of their importance. *Corticium nagum* appears to be the most important parasite of damping-off in most species.
KEYW Disease survey, damping off.

245 AUTH Hartmann, R. K., Querengasser, R., Jahn, G.
DATE 1953

TITL Unterlagen fur den Anbau Westamerikanischer Nadelholzarten in Deutschland.
PUBL Allgemeine Forst- und Jagdzeitung. 125(1): 25-47.
ABST Summarizes planting data for western North American coniferous species in Germany, including western white pine. A summary table for each species is given.
KEYW Planting Germany.

246 AUTH Harvey, A. E.
DATE 1967
TITL Effect of phytoactin treatment on mycorrhizae-root consociations in western white pine.
PUBL Plant Disease Reporter. 51: 1012-1013.
ABST Applications of phytoactin 1,000 times greater than that (200 ppm) which has been applied to western white pine forests had no effect on the formulation or maintenance of normal mycorrhizal systems of 6-year-old seedlings.
KEYW Phytoactin, mycorrhizae-root associations.

247 AUTH Harvey, A. E.
DATE 1967
TITL Tissue culture of *Pinus monticola* on a chemically defined medium.
PUBL Canadian Journal of Botany. 45: 1783-1787.
ABST Procedures for obtaining and maintaining axenic tissue cultures of *Pinus monticola* are described. Western white pine tissue was cultured on a chemically defined medium containing calcium nitrate, magnesium sulfate, potassium phosphate (monobasic), ammonium sulfate, ferric sulfate, manganese sulfate, glucose, and one of three auxins, IAA, NAA, or 2,4-D. Addition of several B vitamins, amino acids, and kinetin increased growth on these media but were not required.
KEYW Tissue culture.

248 AUTH Harvey, A. E., Graham, S. O.
DATE 1969
TITL An effect of phytoactin treatment on western white pine seedlings.
PUBL Phytoprotection. 50: 53-58.
ABST The biological effects elicited by phytoactin against white pine blister rust may be the result of alterations in the protein metabolism of the host. Analyses have shown a general reduction in eight protein-bound amino acids in current-year needles 3 months after treatment with phytoactin. Also, the level of free aspartic acid increases in mature needles during this time. One year after treatment free aspartic acid decreased in current-year needles and free glumatic acid and alanine increased in mature needles.
KEYW Phytoactin, protein metabolism, aspartic acid, glumatic acid, alanine.

249 AUTH Harvey, A. E., Graham, S. O.
DATE 1969
TITL The extraction and assay of fungicidally active phytoactin from western white pine tissues.
PUBL Bulletin 715. Pullman, WA: Washington State Agricultural Experiment Station. 6 p.
ABST Phytoactins A and B were extracted and assayed as separate fractions from treated western pine tissues. Efficiency in extracting was dependent on removal of all free moisture and on the particle size of the sample. Anion gel filtration, followed by precipitation and collection of each fraction onto cellulose acetate filters, provided the means of isolation. These filters provided suitable assay disks for a modified paper disk plate assay. The method was quantitative and free from adsorptive complications.
KEYW Phytoactin, fungicidal assay.

250 AUTH Harvey, A. E., Grasham, J. L.
DATE 1969
TITL Procedures and media for obtaining tissue cultures of 12 conifer species.
PUBL Canadian Journal of Botany. 47: 547-549.
ABST Procedures for obtaining axenic tissue cultures of *Abies grandis*, *Larix occidentalis*, *Picea abies*, *Picea engelmannii*, *Picea pungens*, *Pinus albicaulis*, *Pinus contorta*, *Pinus flexilis*, *Pinus nigra*, *Pinus ponderosa*, *Pseudotsuga menziesii*, and *Thuja plicata* are described. All species were cultured on a basal medium containing calcium nitrate, magnesium sulphate, potassium phosphate (monobasic), ammonium sulfate, ferric sulfate, manganese sulfate, glucose, 3.8 percent bacto agar, and one of three auxins (indoleacetic acid (IAA), naphthaleneacetic acid (NAA), or 2,4-dichlorophenoxyacetic acid (2,4-D)) at various concentrations. Growth of most species was further enhanced by the addition of several vitamins and amino acids. These species were relatively specific in their auxin requirements. The type of sterilant (H_2O_2, NaOCL) and manipulation required in the preparatory procedures were also specific for individual species. Results are compared to previous results with western white pine.
KEYW Tissue culture.

251 AUTH Hedlin, A. F.
DATE 1957
TITL A comparison of insect species on pole blighted and healthy western white pine, *Pinus monticola* Dougl.
PUBL Bi-monthly Progress Report. 13(6): 1-2.

ABST The purpose of the study was to determine what insect species were associated with healthy and pole-blighted white pine trees. Results did not provide conclusive evidence that insects and mites are, in fact, responsible for or associated with the pole blight condition. Comparisons between healthy and pole blighted trees further suggest that the invertebrate fauna feeding activities do not contribute directly to pole blight of white pine. It is possible that some of the species found only on pole-blighted trees may act as vectors for the condition.
KEYW Pole blight, *Hylobius* larvae, mites.

252 AUTH Heimburger, C.
DATE 1961
TITL Comments.
PUBL Recent Advances in Botany. 2(14): 1699-1703.
ABST Problems concerning forest tree breeding are discussed. The author cites several efforts to improve on parent tree breeding. The inducement of early flowering, use of vegetative propagation, and hybrids are discussed.
KEYW Rooting, pine hybrids, mass propagation.

253 AUTH Heimburger, C.
DATE 1963
TITL The breeding of white pine for resistance to weevil.
PUBL In: World consultation on forest genetics and tree improvement; Stockholm, Sweden; (FAO) Section 6b. 2 p.
ABST The level of weevil resistance in *Pinus strobus* is compared to *P. peuce* and *P. monticola*. A breeding program is suggested with the purpose of transferring resistance from *P. peuce* and *P. monticola* to *P. strobus*.
KEYW Weevil, *Pissodes strobi*, *Pissodes approximatus*, resistance, grafting.

254 AUTH Helmers, A. E.
DATE 1936
TITL Effect of pruning on growth of western white pine.
PUBL Journal of Forestry. 44: 673-676.
ABST Pruning for production of clear lumber was being recognized more and more as a desirable silvicultural measure. The author's study on western white pine confirmed earlier findings on other species that not more than one-third of the live crown should be removed in any pruning operation.
KEYW Pruning, height growth, mortality, diameter growth, stand density.

255 AUTH Helmers, A. E.
DATE 1946
TITL Direct seeding western white pine—fifth-year results.
PUBL Research Note 44. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST These experiments show that reforestation of white pine by sowing seeds in spots can be successfully accomplished when adequate protection from seed-eating rodents is provided and the sowing is done in the fall on newly burned north slopes and flats. Poisoning the areas with 1 pound of thallium sulphate-coated hulled sunflower seeds per acre 1 week before sowing appears to provide the necessary protection. Although a test of broadcast sowing resulted in better stocking than seed spotting in that particular instance, broadcast sowing must be more thoroughly tested before conclusions can be made. Seed spot sowing was successfully accomplished on an administrative scale at about the same cost as that of planting nursery seedling stock.
KEYW Direct seeding.

256 AUTH Helmers, A. E.
DATE 1946
TITL How heavily should western white pine be pruned?
PUBL Research Note 41. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Three tests were initiated in the fall of 1940 to determine the height to which western white pine trees can be pruned without seriously retarding growth. The evidence indicates that only about one-third of the live crown can be removed without substantially lowering the rates of growth, both in diameter and in height.
KEYW Pruning.

257 AUTH Helmers, A. E.
DATE 1946
TITL Pruning wound healing on western white and ponderosa pines.
PUBL Research Note 45. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 6 p.
ABST These experiments indicate that pruning is most effective in young plantations or in moderately open young natural stands. In such stands, pruning to a height of 17 ft will require two or three successive operations. Conditions affecting the rate of healing are partially compensating. In very open stands, for example, the large branches result in large wounds but the trees are relatively fast-

growing and most of the branches are alive when pruned. In dense stands, the trees usually grow more slowly, and most of the limbs are dead when pruned; but, on the other hand, the limbs tend to be small. Close pruning results in smaller knotty cores and more rapid wound healing. However, this method of pruning takes more time because of the larger area of the cuts, and the greater care required to cut accurately and closely. Optimum conditions for rapid wound healing result from close pruning small live branches on rapidly growing trees.
KEYW Pruning.

AUTH Helmers, A. E.
DATE 1948
TITL Early results from thinning seed spots.
PUBL Research Note 58. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST The results of this experiment show that, although the effect of number of seedlings per seed spot on the height growth is of little practical consequence, there is a pronounced effect on diameter growth of 9-year-old Engelmann spruce, western white pine, and ponderosa pine seedlings originating from direct sowing. These early results do not prove or disprove the need for thinning seed spots.
KEYW Thinning, direct seeding.

AUTH Hepting, G. H.
DATE 1971
TITL Western white pine: *Pinus monticola*.
PUBL In: Diseases of forest and shade trees of the United States. Agriculture Handbook 386. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 322-326.
ABST Gives a brief description of the tree species and then lists seedling diseases, foliage diseases, stem diseases, root diseases, trunk rots, and mycorrhizal relations.
KEYW Diseases, seedlings, stem, foliage, roots, trunk, mycorrhizae.

AUTH Hermann, A.
DATE 1960
TITL Western pine glued-cleat sheathing panel.
PUBL Western Pine Association Research Note 8. p. 7-101.
ABST Testing of western white pine glued-cleat sheathing panels was undertaken in an attempt to improve marketability of the product. The author recommends certain construction criteria for the sheathing and lists suggested applications.
KEYW Utilization, wood sheathing.

261 AUTH Hill, R. B.
DATE 1959
TITL A study of leader elongation in western white pine.
PUBL Moscow, ID: University of Idaho. 52 p. M.S. thesis.
ABST In a study of leader elongation in western white pine, progenies from control-pollinations and grafts made from rust-resistant selections were measured for leader growth on two plots during the growing period in 1958. Progenies selected were descended from fast-growing and slow-growing parents growing at two elevations with a difference in altitude of 2,150 ft. Growth points of 5, 50, and 95 percent were computed for a selected group of progenies, and grafts chosen to represent the differences in altitude of their origin and their parents' growth rates. Also, the time or date when these growth points were reached was computed. The progenies and grafts displayed differences in amount of leader elongation consistent with their parents' differences in most, but not all, cases. The amount of leader growth was significantly different between two fast-growing progenies: one from a high elevation seed source and the other from a low altitude. The progenies from the low altitudes made the best growth. An "f" test disclosed significant difference due to elevation on one plot. Cessation of leader elongation was markedly different in one plot in a comparison between progenies from different elevations leading to the conclusion that the cessation of height growth is probably under genetic control. Rate of growth was also affected here and is probably a hereditary factor.
KEYW Leader elongation, provenance test.

262 AUTH Hobbs, S. D., Partridge, A. D.
DATE 1979
TITL Wood decays, root rots, and stand composition along an elevation gradient.
PUBL Forest Science. 25(1): 31-42.
ABST Seventy-four randomly selected stands of mixed conifers were examined for wood-decaying fungi in northern Idaho during 1974 and 1975. Stands were ordinated two-dimensionally based on the presence of all vascular plants. The ensuing ordination approximated an elevation gradient. An agglomerative cluster analysis was used to classify stands into discrete units based on the presence of coniferous trees. The wood decaying fungi identified were *Armillaria mellea, Echinodontium tinctorium, Phellinus pini, Phaeolus schweinitzii, Polyporus sericeomollis, Inonotus tomentosus, Perenniporia subacida*, and *Phellinus weirii*.

Fungi distributions and stand composition changed with increasing elevation.

KEYW Agglomerative cluster analysis, ordination, succession, wood decaying fungi.

263 AUTH Hoekstra, P. E., Merkel, E. P., Powers, H. R.
DATE 1961
TITL Production of seeds of forest trees.
PUBL In: Yearbook of Agriculture. Washington, DC: U.S. Department of Agriculture. 227-232.
ABST This article gives an overview of forest tree seed production in the United States. Genetic quality of most of the tree seed being produced (in 1961) was unknown. Various programs are discussed.
KEYW Seed production, seed orchards.

264 AUTH Hoff, R. J.
DATE 1968
TITL Chemical verification of the hybrid of *Pinus monticola* and *Pinus flexilis.*
PUBL Forest Science. 14: 119-121.
ABST A positive identification of the hybrid seedlings of *Pinus monticola* and *P. flexilis* can be made by chromatographic techniques. *Pinus monticola* extracts contain a phenolic compound lacking in *P. flexilis* and conversely *P. flexilis* extracts contain a compound lacking in *P. monticola.* The hybrid extracts contain both compounds.
KEYW *Pinus monticola* x *P. flexilis*, phenols, chromatography.

265 AUTH Hoff, R. J.
DATE 1977
TITL Delayed graft incompatibility in western white pine.
PUBL Research Note INT-215. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST A form of graft incompatibility was observed 11 years after a seed orchard of grafted western white pine was established. After 16 years, over 60 percent mortality had occurred in four of the 13 clones studied, and two more were beginning to show symptoms of graft incompatibility.
KEYW Graft incompatiblity, seed orchards, graft seed orchard.

266 AUTH Hoff, R. J.
DATE 1981
TITL Cone production of western white pine seedlings and grafts.
PUBL Research Note INT-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Grafts of western white pine planted in a seed orchard within the white pine type produced six cones per tree 11 years after grafting; grafts of the same families in a breeding arboretum located on a grassland habitat produced 1.6 cones per tree 14 years after grafting. Seedlings in the breeding arboretum produced 1.2 cones per tree at 12 years of age. Placement of seed orchards of western white pine is discussed.
KEYW Cone production, seed orchards, grafts.

267 AUTH Hoff, R. J., Coffen, D. O.
DATE 1982
TITL Recommendations for selection and management of seed orchards of western white pine.
PUBL Research Note INT-325. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p.
ABST Seed orchards of western white pine should be located on flat sites within the botanical range of western white pine. They should be planted at a 6- by 6-m spacing, and they should be sprinkler irrigated, fertilized in August with 300 lb/acre ammonium nitrate, and sown with grass. Trees should be top pruned at 3 m and managed so that they develop three to four tops. Basal branches should be pruned to provide fire and rodent protection. A mechanical lift should be used to harvest cones when they are starting to open. Trees should be sanitized by removing all cones to decrease insect infestation. All trees should be tagged and the amount of pollen, number of cones, ripening day, and seed-germination capacity recorded for each individual tree.
KEYW Seed orchards, seed orchard management.

268 AUTH Hoff, R. J., McDonald, G. I.
DATE 1968
TITL Rooting of needle fascicles from western white pine seedlings.
PUBL Research Note INT-80. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST In one test, 45 out of 318 (14 percent) needle fascicles from 2-year-old seedlings of *Pinus monticola* were rooted. Eight of the needle fascicles produced shoot growth. In another test, 392 out of 742 (53 percent) needle fascicles were rooted, but none of these produced shoot growth.
KEYW Rooting, needle fascicles, cultural treatments.

9 AUTH Hoff, R. J., McDonald, G. I.
DATE 1977
TITL Differential susceptibility of 19 white pine species to woolly aphid (*Pineus coloradensis*).
PUBL Research Note INT-225. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Several species of white pine appeared to be completely resistant to woolly aphid; others were highly susceptible. The level of infestation tended to be highest for species in subsection *Strobi,* for species from the North American continent, and for species that are most susceptible to white pine blister rust.
KEYW Woolly aphid, *Pineus coloradensis*, resistance (insects).

0 AUTH Hoff, R. J., McDonald, G. I.
DATE 1978
TITL Genetic variation in susceptibility of western white pine to needle blight.
PUBL Research Note INT-249. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Ten clones of western white pine differed in their susceptibility to white pine needle blight. Two clones were significantly less infected than the average. This variability suggests a simple inheritance, maybe just one or two genes.
KEYW White pine needle blight, *Lecanosticta*, disease resistance.

1 AUTH Hoff, R. J., Steinhoff, R. J.
DATE 1980
TITL Comparative growth rates of western white pine varieties resistant to blister rust.
PUBL Research Note INT-290. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 5 p.
ABST The growth of seedlings of western white pine that displayed specific mechanisms of resistance in response to white pine blister rust was compared. These growth statistics were then compared to those of seedlings that had blister rust cankers. No difference was detected among these categories.
KEYW Growth and blister rust resistance.

2 AUTH Hoff, R. J., Steinhoff, R. J.
DATE 1984
TITL Short internodes in western white pine.
PUBL Research Note INT-344. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p.
ABST Irregularities in growth at the top of western white pine trees were related to three causes: (1) death of the terminal bud while dormant, (2) current-year terminal killed by insects, and (3) succulent terminal broken (usually by birds). In about half the cases, the broken succulent terminal also dies. In all irregularities related to causes 1 and 2, and those of cause 3 where the terminal died, lateral branches turned upward to replace the terminal, resulting in a moderate growth loss. On the broken succulent terminals that survived, one or more fascicular buds appeared. Evidence that such fascicular buds develop into new terminals was seen on growth from preceding years, and it is presumed that those on the current year's growth will also do so. In most cases, however, the internode will be very short for the year in which breakage occurs.
KEYW Western white pine, short internodes, tree top damage.

273 AUTH Hofmann, J. V.
DATE 1917
TITL Natural reproduction from seed stored in the forest floor.
PUBL Agricultural Research. 11: 1-26.
ABST The study of burns and cut-over areas in the Douglas-fir region of the Pacific Northwest has brought out the following facts: (1) The distance to which seed trees are capable of restocking is limited to from 150 to 300 ft. They cannot, therefore, account for the restocking of the large burned areas. (2) The irregular, dense stands of young growth are due to seed stored in the forest floor or in cones. This seed retains its viability through the fire and is responsible for the dense reproduction that springs up after the first fire. (3) The even-aged stands of reproduction immediately following a fire (regardless of location of remaining seed trees), the irregular alternation of dense stands of reproduction with grass areas, and the failure of reproduction on areas burned over by a second fire before the stand reaches seeding age or by consuming all of the duff and precluding any possibility of seed remaining after the fire, all point to the seed stored in the duff as the principal source of seed responsible for the restocking. (4) The ability of the seed to retain its viability when stored in the duff or when retained in cones during fires has been further demonstrated by recovering and germinating seed from duff under forest conditions and by recovering and germinating seed from cones which passed through a crown fire. In this study, the mature forest before the burn contained about 5

percent white pine; after the burn, reproduction constituted 10 percent of the stand.
KEYW Seed storage, natural reproduction, duff storage—seed, restocking, seed viability, reproduction after fire.

274 AUTH Hofmann, J. V.
DATE 1918
TITL The importance of seed characteristics in the natural reproduction of coniferous forests.
PUBL Bulletin 2. Minneapolis, MN: University of Minnesota. 25 p.
ABST All forest tree species in forest stands produce sufficient seed to reestablish their own type under favorable conditions, and a change of type or removal of a forest from any area once covered with a forest is due to other factors than production of seed. Species producing large seeds produce comparatively few in number. Seed distribution is one of the important factors controlling the establishment of a forest type. In the white pine region of Idaho, reproduction by wind-blown seed cannot be depended upon for more than 150 feet from the seed trees. Germination conditions are often unfavorable in a shaded and cool forest floor; hence, seed may lie dormant for long periods. By the removal of a forest, germinating conditions are improved, and the dormant seed germinates. Moisture is the chief factor in the establishment of the seedling, while temperature is often a more important factor in germination. A seedling from a large seed becomes permanently established much earlier than a seedling grown from a small seed, hence the former is able to obtain and hold possession of the more favorable sites. Some seed, while dormant, will withstand severe conditions, as shown by chemical tests. Coniferous seeds are known to be viable after 2 to 8 years of storage in the forest floor.
KEYW Seed characteristics, seed distribution, seed migration, seed germination, seed size, seed viability, chemical treatment—seed.

275 AUTH Holmes, P. N.
DATE 1947
TITL 1945 lumber production in the Northern Rocky Mountain Region.
PUBL Research Note 49. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The following statistics are given for western white pine: total lumber production in 1944 was 292,330 thousand bd ft; in 1945, 238,364 thousand bd ft, showing an 18 percent decrease.
KEYW Production lumber.

276 AUTH Howard, J. O.
DATE 1973
TITL The timber resources of central Washington.
PUBL Research Bulletin PNW-45. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 68 p.
ABST Gives area of commercial forest land by type, species, diameter, county, and ownership. The following figures are given for western white pine in central Washington as of January 1, 1968: area of commercial forest land, 13,000 acres; number of growing stock trees, all classes, 5,975 thousand; volume of all growing stock, 136 million cubic feet; volume of sawtimber, 707 million bd ft.
KEYW Commercial forest area, growing stock, growing stock volume, sawtimber volume, forest survey, forest appraisal, Washington.

277 AUTH Howe, J. P., Bently, M. M., Bricker, C. O.
DATE 1973
TITL The production of bark in Idaho's forest industries.
PUBL Note 20. Moscow, ID: University of Idaho, Forestry, Wildlife, and Range Experiment Station. 4 p.
ABST Bark production for western white pine in Idaho is listed as 92,092 units for 1971-1972. Bark production by species and counties is also listed.
KEYW Bark production, Idaho.

278 AUTH Huberman, M. A.
DATE 1935
TITL The role of western white pine in forest succession in northern Idaho.
PUBL Ecology. 16: 137-151.
ABST This paper discusses the character of the vegetation of the subclimax and near-climax forests of the "western white pine type" in northern Idaho. Phytographs were constructed using data on size-class distributions, abundance and frequency percentages, and basal area. Evidence shows that white pine appears mostly in the early stages of succession, playing a very minor part in the climax forest. A discussion of the successional relationships of western white pine points to an early cutting age as a means of preventing the replacement of this species by the less valuable climax species.
KEYW Succession status.

279 AUTH Hubert, E. E.
DATE 1920
TITL The disposal of infected slash on timber-sale areas in the Northwest.
PUBL Journal of Forestry. 18: 34-56.
ABST Reports on studies of factors affecting sporophore production and makes suggestions for

forest sanitation. It was found that all of the most destructive wood rotting fungi operating in the forests of the Northwest develop fruiting bodies on their hosts after the tree is cut. Hubert believed slash furnishes a serious source of infection to the remaining stand. *Trametes pini* sporo-phores were recovered from infected slash of western white pine.
KEYW Slash disposal, wood rotting fungi, forest sanitation, *Trametes pini*.

280 AUTH Hubert, E. E.
DATE 1923
TITL Contribution to McNary Committee Report.
PUBL Unpublished manuscript on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Moscow, ID.
ABST Summarizes knowledge concerning disease losses in forests of Montana and Idaho. White pine is listed as approximately one-third of the timber resource in Idaho but only 2 percent in Montana. Diseases listed for standing green timber are heart rots, root rots, and needle diseases.
KEYW Fungi, false mistletoes, loss estimates, timber resource.

281 AUTH Hubert, E. E.
DATE 1925
TITL Forest diseases and losses with figures to demonstrate the toll of fungi and disease.
PUBL The Timberman. 25(1): 225-226.
ABST Gives an overview of the disease problem in Oregon, Washington, and northern California forests. Estimated percent defect in western white pine was 2.5-3.0 percent in Oregon and Washington, the lowest of any species listed.
KEYW Fungi, disease losses, percent defect.

282 AUTH Hubert, E. E.
DATE 1926
TITL The brown stains of lumber.
PUBL The Timberman. 26(5): 44-50.
ABST Discusses brown stains in pine lumber at length. Causes for the stains in western white pine are listed as certain combinations of temperature and relative humidity during kiln drying, machine or kiln burns, water stain, and fungi.
KEYW Brown stain, kiln drying, yard drying.

283 AUTH Hubert, E. E.
DATE 1927
TITL Manual of wood rots for cruisers and scalers in the Inland Empire.
PUBL The Timberman. January p. 27-46; February p. 43-48; March p. 48-52; April p. 48-53.
ABST The following wood rots are described for western white pine: *Trametes pini* (red ring rot), *Polyporus schweinitzii* (red brown butt rot), root rots (*Fomes annosus*, *Poria subacida*), white pocket rots (in downed timber), white pine blister rust.
KEYW Wood rot, *Trametes pini*, *Polyporus schweinitzii*, *Fomes annosus*, *Poria subacida*, white pocket rot, root rots.

284 AUTH Hubert, E. E.
DATE 1930
TITL Winter injury of conifers.
PUBL Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Moscow, ID.
ABST Report consists of two tables summarizing winter injury and other damage to conifers from 1908 to 1929.
KEYW Winter injury of conifers.

285 AUTH Hubert, E. E.
DATE 1932
TITL The honey mushroom in white pine stands.
PUBL Unpublished manuscript on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Moscow, ID.
ABST *Armillaria mellea* is prevalent throughout the white pine type in Idaho, and is often noted in thrifty dense stands of young white pine. The disease takes a heavy toll in coniferous forests, but the losses are not easily evaluated. The fungus is parasitic, attacking the sapwood and killing the cambium of the infected trees.
KEYW *Armillaria mellea*

286 AUTH Hubert, E. E.
DATE 1949
TITL Pole blight: a summary of information and suggested tests.
PUBL Unpublished manuscript on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Moscow, ID.
ABST Summarizes what is known about pole blight and suggests future research. Fungi listed are: *Armillaria mellea*, *Fomes annosus*, *Poria subacida*, *Sparassis radicata*; and *Rhizina inflata*. The principal insect listed was *Dendroctonus ponderosae*.
KEYW *Fomes annosus*, *Poria subacida*, *Sparassis radicata*, *Rhizina inflata*, pole blight, *Armillaria mellea*, *Dendroctonus ponderosae*.

287 AUTH Hubert, E. E.
DATE 1950

TITL Rootrots of the western white pine type.
PUBL Northwest Science. 24(1): 5-17.
ABST Reports on an intensive study made of the four most important root rots of the western white pine type: *Armillaria mellea*, *Poria subacida*, *Fomes annosus*, and *Poria weirii*. Symptoms, signs, and cultural characteristics of four root rot species are compared. Root rot control is also discussed.
KEYW *Armillaria mellea*, *Poria subacida*, *Fomes annosus*, *Poria weirii*, root rots, decay, root rot control.

288 AUTH Hubert, E. E.
DATE 1951
TITL Hubert making study of Idaho pine pole blight.
PUBL The Forest Log. 20(10): 2.
ABST Describes Hubert's work with pole blight.
KEYW Pole blight.

289 AUTH Hubert, E. E.
DATE 1953
TITL Studies of *Leptographium* isolated from western white pine.
PUBL Phytopathology. 43: 637-641.
ABST The objective of this study was to determine if *Leptographium* spp. could be considered a primary cause of pole blight and to gain some information regarding phytotoxins produced by this fungus. Inoculation experiments established the ability of this organism to produce lesions in the bark of its host and to cause death of seedlings under certain conditions. Wounding of the bark proved to be necessary for infection. Similar species apparently differing in virulence were found both within and outside the present known spread limits of pole blight. The inoculation and phytotoxin tests indicated that *Leptographium* spp. is not a primary cause of death of trees showing pole blight symptoms.
KEYW Pole blight, *Leptographium*, phytotoxins, inoculation.

290 AUTH Hubert, E. E.
DATE 1953
TITL A study of recently killed trees in the western white pine type.
PUBL Journal of Forestry. 51: 624-627.
ABST The prevalence of agents other than pole blight found associated with recently killed trees is reported.
KEYW Mortality, pole blight, *Armillaria mellea*.

291 AUTH Hubert, E. E.
DATE 1955
TITL Translocation of past bark lesions on young western white pine.
PUBL Plant Disease Reporter. 39(6): 500-503.
ABST This study reports findings of tests conducted to trace upward and downward movement of radio-phosphorus past bark lesions on western white pine. The fungus used to produce the lesions was a species of *Leptographium*, isolated from a root of a pole-blighted tree. Branch and stem lesions had no appreciable effect on the movement of the tracer. However, tracer movement upward past root lesions was greatly curtailed. This is supported by microscopic examination, which shows greater deterioration of tissues in root lesions when compared with branch or stem lesions. It is postulated that tracer recovered beyond lesions was transported by the xylem.
KEYW *Leptographium*, pole blight, bark lesions, tracer, radio-phosphorus.

292 AUTH Hubert, E. E., Ferrell, W. K.
DATE 1952
TITL Radioisotope tests of translocation in artificially infected *Pinus monticola* Dougl.
PUBL Phytopathology. 42: 515. Abstract.
ABST The University of Idaho was conducting studies to determine the cause of a new damaging disease of western white pine known as pole blight. Symptoms of this disease were appearing on 60,000 acres of pole size timber in northern Idaho, western Montana, and British Columbia, and many trees were dying. Tests were being conducted to determine the effect on translocation in the tree of certain fungi isolated from pole blighted trees. Radioactive phosphorus was introduced into the xylem and the phloem to determine whether the bark lesions resulting from artificial inoculations caused any changes in translocation or absorption of the introduced solutions. The first series of tests were conducted using cultures of *Leptographium* spp. as the inoculum on root, trunk, and branch tissues of small saplings in the greenhouse. Some evidence based on preliminary results indicated that bark lesions on the trunk seriously obstructed the downward movement of P32 in the phloem.
KEYW Radioisotopes, translocation, artificial inoculation, *Leptographium*.

293 AUTH Huey, B. M.
DATE 1950
TITL The profit in pruning western white and ponderosa pine.
PUBL Research Note 85. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 6 p.
ABST Pruning of both of the western pines appears to be a profitable forest practice. For

example, a pruned butt log of white pine, having a 4-inch knotty core and harvested at 21 inches d.b.h., will yield $48.56 more per thousand (in 1950) after pruning costs than an identical unpruned log.
KEYW Pruning.

AUTH Hughes, P. R.
DATE 1973
TITL Effect of a-pinene exposure on trans-verbenol synthesis in *Dendroctonus ponderosae* Hopk.
PUBL Naturwissenschaften. 60: 261-262.
ABST Exposure of both sexes of *Dendroctonus ponderosae* to air saturated with a-pinene rapidly initiates or increases the biosynthesis of trans-verbenol, which acts as this insect's principal aggregating pheromone.
KEYW *Dendroctonus ponderosae,* trans-verbenol synthesis.

AUTH Hungerford, R. D.
DATE 1973
TITL Drought crack on western white pine in northern Idaho.
PUBL Forest Science. 19: 77-80.
ABST In September of 1967, one western white pine in northern Idaho had external cracks which were not apparent 3 months earlier. This fact, together with observation of climatic data, site conditions, and wood anatomy, suggest that cracking resulted from moisture stress. Inherent structural weaknesses of the wood apparently predisposed the tree stem to cracking during the drought.
KEYW Xylem, moisture stress, tracheids, drought crack.

6 AUTH Hunt, R. S., Von Rudloff, E.
DATE 1977
TITL Leaf-oil terpene variation in western white pine populations of the Pacific Northwest.
PUBL Forest Science. 23: 507-516.
ABST The volatile leaf oil of western white pine was analyzed. In addition to the typical monoterpenes, (-) ß-elemene, caryophyllene, as well as (-) ß-selinene, cadinene isomers and their corresponding alcohols, and manool were isolated. The quantitative variation within tree, from tree to tree, and among populations from British Columbia and Washington was determined. The composition of the leaf oil from known healthy trees or resistant crosses was compared with that of blister rust-infected trees; no correspondence between disease resistance and terpene composition was found. The foliage of one heavily infected tree had a markedly different quantitative terpene composition on resampling 1 year later. Other healthy or infected trees showed no change. One hundred and eighty trees from 10 coastal and 10 interior populations were sampled. Within-population variation was generally much higher than that between populations, and most monoterpene, all sesquiterpene, and the manool percentages showed no regional differences. Minor clustering of populations from Vancouver Island and the Olympic Peninsula on the basis of ß-pinene was found; those from the Cascade Mountains clustered with interior populations.
KEYW Chemosystematic study, leaf-oil terpene variation, monoterpenes, sesquiterpenes, provenance test.

297 AUTH Hutchison, S. B.
DATE 1938
TITL A century of lumbering in northern Idaho. Parts I-III.
PUBL The Timberman. 39(10): 20-21, 26; 39(11): 15, 28; 39(12): 35-36, 38-39.
ABST This three-part article gives a historic account of lumbering activities in northern Idaho. The importance of western white pine as a timber species during this early period is well documented.
KEYW Lumbering, history.

298 AUTH Hutchison, S. B.
DATE 1948
TITL Comparative marketability of pine and mixed species in the Inland Empire.
PUBL Research Note 64. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST These charts document the wide difference between the pine indexes and the indexes for the mixed species. Regardless of how the position of the mixed species changes in coming years, the wide margin between the indexes for these species and the indexes for ponderosa pine and white pine will probably continue. White pine has been a preferred species in the United States for three centuries. For the shorter period, since the West was opened up, ponderosa pine has likewise been preferred. There is no sign that this preference, which has meant higher prices and higher profits, will not continue.
KEYW Marketability.

299 AUTH Hutchison, S. B., Kemp, P. D.
DATE 1952
TITL Forest resources of Montana.
PUBL Forest Resource Report 5. Washington, DC: U.S. Department of Agriculture. 76 p.
ABST Western white pine was the least common species listed for Montana, with 0.2 billion

cubic feet for all timber and 1.1 billion bd ft for sawtimber. However, white pine and its three associates occupied some of the most productive forest land in the State.
KEYW Forest resource, Montana, timber supply.

300 AUTH Hutchison, S. B., Winters, R. K.
DATE 1942
TITL Northern Idaho forest resources and industries.
PUBL Miscellaneous Publication 508. Washington, DC: U.S. Department of Agriculture. 75 p.
ABST The paper stressed the fact that western white pine was being cut disproportionately to other species. Allowable annual cut for western white pine was 140 million bd ft; actual cut was 351 million bd ft. The great overcut of western white pine was on lands other than National Forests. The paper predicted an annual cut of western white pine as low as 70 million bd ft by 1959 if the present drain continued.
KEYW Forest resource, northern Idaho, industry, ownership, fire, economy, allowable annual cut.

301 AUTH Isaac, L. A.
DATE 1930
TITL Seed flight in the Douglas-fir region.
PUBL Journal of Forestry. 28: 492-499.
ABST Some of these tests were from a box kite at 100-ft elevation and some from a pilot balloon at 150-ft elevation. White pine seed was disseminated farther than yellow (ponderosa) pine or Douglas-fir in the balloon test. Overall results indicate that the abundance of the crop, height of release, wind velocity, and tree species all have a bearing on distance and density of seed distribution.
KEYW Seed flight, seed fall.

302 AUTH Jackson, M. T., Faller, A.
DATE 1973
TITL Structural analysis and dynamics of the plant communities of Wizard Island, Crater Lake National Park.
PUBL Ecological Monographs. 43: 441-461.
ABST *Pinus monticola* is listed as an important tree species (the only one other than *Abies magnifica* and *Tsuga mertensiana*) on Wizard Island, Crater Lake, OR.
KEYW Crater Lake, Oregon, distribution.

303 AUTH Jantz, O. K., Rudinsky, J. A.
DATE 1965
TITL Laboratory and field methods for assaying olfactory responses of the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins.
PUBL Canadian Entomologist. 97: 935-941.
ABST Laboratory tests revealed that female Douglas-fir beetles, *Dendroctonus pseudotsugae*, boring in logs of both host and nonhost species produce a volatile substance that both attracts and arrests adult beetles. Male arrestment provided a reliable method for laboratory bioassay of volatile substances. Field tests were devised to show the attack, the attraction produced, and the broad development in six tree species: Douglas-fir, western larch, ponderosa pine, western hemlock, western white pine, and grand fir.
KEYW *Dendroctonus pseudotsugae*, olfactory response, attractants, attack insect, brood development.

304 AUTH Jayne, B. A.
DATE 1960
TITL Some mechanical properties of wood fibers in tension.
PUBL Forest Products Journal. 10: 316-322.
ABST Load-deformation properties of single fibers of wood were measured by means of an electrical-mechanical system for measuring force and deformation. Data from tests of 10 coniferous trees show vast differences between species and often between earlywood and latewood fibers of a single species.
KEYW Wood fiber, load deformation, early wood, late wood, wood stress properties.

305 AUTH Jenkins, M. J.
DATE 1982
TITL Western white pine: the effect of clone and cone color on attacks by the mountain pine cone beetle.
PUBL Logan, UT: Utah State University. 91 p. Ph.D. dissertation.
ABST The relationship between clone and cone color in western white pine, *Pinus monticola*, to attack by the mountain pine cone beetle, *Conophthorus monticolae*, was studied in the Sandpoint Seed Orchard, Idaho. A positive relationship was shown to exist during a 5-year field evaluation. Cone beetles were found to prefer dark-colored cones and to attack certain clones at a higher rate than others. Laboratory dissections did not indicate that cone color affected oviposition, brood development, or brood mortality. Olfactometer experiments demonstrated that olfactory stimuli are involved in the cone beetle attack sequence. Visual cues relating to cone color may be involved in the initial long-range host orientation of attacking beetles.
KEYW Mountain pine cone beetle, *Conophthorus monticolae*, cone color, resistance to cone beetle.

306 AUTH Jenkins, M. J.
DATE 1983

TITL Relationship between attacks by the mountain pine cone beetle (*Coleoptera: Scolytidae*) to clone and cone color in western white pine.
PUBL Environmental Entomology. 12(4): 1289-1292.
ABST Total cones produced by western white pine and total number attacked by the mountain pine cone beetle (*Conophthorus ponderosae = C. monticolae*) were counted during a 5-year study in the Sandpoint Seed Orchard, Sandpoint, ID. Cone production and level of beetle attack varied with clone, cone color class, and year. Certain western white pine clones were attacked at consistently higher rates than other clones. In years when cone production and percentage of cone attack were high, cone beetles showed preference for dark-colored over light-colored cones.
KEYW Mountain pine beetle, cone color, resistance to mountain pine beetle.

7 AUTH Jenkins, S. J.
DATE 1939
TITL Selective logging in Idaho.
PUBL Trees Magazine. 2(2): 9-15.
ABST Here is a plan of permanent forest management; the entire area is classified into four types of stands: (1) White pine dominates by more than 70 percent. Sixty percent of the volume is cut, but under no circumstance is any tree taken that has a diameter at breast height of less than 17 inches. (2) White pine in dominance from 40 to 69 percent. Here, half the volume is removed with the average diameter 14 to 16 inches. (3) Other species predominate and the white pine stands only 10 to 39 percent. Forty percent of this volume is taken, including some mixed species, with about the same diameter limits as in type two. (4) The mixed species type where white pine is less than 10 percent of the stand. None of this type is cut.
KEYW Selective logging.

08 AUTH Johnson, F. A.
DATE 1955
TITL Volume tables for Pacific Northwest trees.
PUBL Handbook 92. Washington, DC: U.S. Department of Agriculture, Forest Service. 122 p.
ABST Contains volume tables for several species, including cubic-foot and board-foot tables for western white pine.
KEYW Volume tables, Pacific Northwest.

09 AUTH Johnson, P. C., Schmitz, R. F.
DATE 1965
TITL *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), a pest of western white and ponderosa pines in the Northern Rocky Mountains: a problem analysis.
PUBL Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID. 87 p.
ABST Largely a study of *Dendroctonus ponderosae,* this report contains information on relationships between the beetle and its host tree. Mechanical injury, foliage and bole deterioration, host tree resistance, and tree vigor classifications are discussed.
KEYW *Dendroctonus ponderosae.*

310 AUTH Johnstone, G. R.
DATE 1940
TITL Further studies on polyembryony and germination of polyembryonic pine seeds.
PUBL American Journal of Botany. 27: 808-811.
ABST Germination tests and dissection of mature seeds show polyembryony multiple seedlings to be present in the 11 species of pine studied. Frequency of occurrence of polyembryony (selective development of multiple seedlings) among the several species is discussed.
KEYW Polyembryony, multiple seedlings, selective development, embryo, pine seed.

311 AUTH Keen, F. P.
DATE 1958
TITL Cone and seed insects of western forest trees.
PUBL Technical Bulletin 1169. Washington, DC: U.S. Department of Agriculture, Forest Service. 168 p.
ABST The bulletin notes that very little information is available on cone damage of western white pine. Insect species listed are: *Conophthorus monticolae*, *Conophthorus lambertiana*, *Doiryctria* sp. (prop. *abietella*), and *Eupithecia spermaphaga*. The only parasite listed is *Bracon* n.sp. near *tachypteri*. Descriptions of each insect and damage caused are included in the bulletin.
KEYW Cone insects, seed insects, *Conophthorus*, *Dioryctria*, *Eupithecia*.

312 AUTH Kellogg, R. M., Rowe, S., Koeppen, R. C., Miller, R. B.
DATE 1982
TITL Identification of the wood of the soft pines of Western North America.
PUBL IAWA Bulletin (New Series). 3: 95-101.
ABST A method is described for identifying the woods of the soft pines of Western North America: western white pine, sugar pine, limber pine, and whitebark pine.
KEYW Wood identification, resin canals.

313 AUTH Kemp, P. D., Metcalf, M. E.
DATE 1948

TITL Tables for approximating volume growth of individual trees.
PUBL Paper 11. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 14 p.
ABST These growth tables were derived from average-height volume tables. Application of these tables requires only a diameter determination and a radial growth measurement, either (1) number of annual rings in the outer radial inch or (2) the number of years (rings) in a specified radial increment in inches. Field checks show that the growth of single trees can be determined from the tables within 15 percent of a precise determination two out of three times. The tables express volume growth in three ways: (1) Annual board-foot (Scribner) growth of trees by diameter class and radial increment. (2) Average annual board-foot (Scribner) growth percent of trees by diameter class and radial increment. (3) Periodic (10 years) board-foot (Scribner) growth of trees by diameter class and radial increment. To facilitate the determination of growth of trees differing in diameter from the midpoint of the class and for growth rates between those indicated, the growth should be plotted over d.b.h. and curved in ordinary cross-section paper. This will not give a precise determination for the individual tree; nevertheless, the curved volumes and tables permit useful approximations of the volume growth of individual trees.
KEYW Volume growth.

314 AUTH Kempff, G.
DATE 1923
TITL Some results of winter slash disposal.
PUBL Applied Forestry Note 41. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Gives results of a test of progressive winter slash disposal in the western white pine type. Winter disposal of slash was shown to be an absolutely safe operation as a fire protective measure. Silviculturally, it was advantageous because less ground cover was burned. Damage to reproduction and reserved trees was held to a minimum. However, financially the method was not economical in this test. Suggestions are given for reducing costs.
KEYW Slash disposal winter.

315 AUTH Kendell Snell, J. A., Brown, J. K.
DATE 1978
TITL Comparison of tree biomass estimators—d.b.h. and sapwood area.
PUBL Forest Science. 24(4): 455-457.
ABST Investigation of 108 small trees ranging in d.b.h. from 0.5 to 19.3 cm for seven western conifer species in western Montana and northern Idaho revealed that, for some species, sapwood cross-sectional area can estimate crown biomass more precisely than external measurements, such as d.b.h.
KEYW Crown weight, biomass, sapwood area.

316 AUTH Kendell Snell, J. A., Brown, J. K.
DATE 1980
TITL Handbook for predicting residue weights of Pacific Northwest conifers.
PUBL General Technical Report PNW-103. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 44 p.
ABST Procedures are given for estimating weights of potential residue from Douglas-fir and western hemlock created by forest management activities west of the summit of the Cascade Range. Preliminary estimates are given for six other species, including western white pine.
KEYW Biomass, residue weights, weight tables.

317 AUTH Kennedy, J.
DATE 1964
TITL Tree planting in the Upper Hunter District.
PUBL Forest and Timber, Sydney. 1(4): 2-5.
ABST It is recommended that reforestation be increased in the Upper Hunter District to help stabilize present erosion and general catchment deterioration. Tree species already successfully established are listed for each of the three areas comprising the District.
KEYW Overgrazing, erosion, streambank stabilization, erosion control, reforestation.

318 AUTH Kennedy, P. C., Fellin, D. G.
DATE 1969
TITL Insects affecting western white pine following direct seeding in northern Idaho.
PUBL Research Note INT-106. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Insect damage to direct-seeded western white pine on three clearcut areas that were prescribed burned in successive years was investigated in north-central Idaho. Ground beetles ate seeds and grasshoppers and cutworms ate seedlings in the field and in the laboratory. The amount of damage to seedlings was inversely related to the age of the burn. Insects only slightly restricted successful first-year development of western white pine following direct seeding.

KEYW Direct seeding, ground beetles, grasshoppers, cutworms.

.9 AUTH Ketcham, D. E., Wellner, C. A., Evans, S. S., Jr.
DATE 1968
TITL Western white pine management programs realigned on Northern Rocky Mountain National Forests
PUBL Journal of Forestry. 66: 329-332.
ABST A comprehensive evaluation of problems of managing western white pine stands in National Forests in the Northern Rocky Mountains completed in 1966 led the U.S. Forest Service to realign its management of this and associated species. Comparative reduction in economic importance of western white pine, coupled with inability of blister rust control programs to protect white pine, strongly influenced the Federal management decision.
KEYW Management, economic importance, protection.

20 AUTH Kidd, F. A., Miller, D. L.
DATE 1983
TITL The effects of Tordon herbicide on planted conifer seedlings.
PUBL Forest Technical Paper TP-83-1. Lewiston, ID: Potlatch Corporation. 6 p.
ABST Picloram, the active ingredient in the herbicide Tordon 101, will injure conifer seedlings planted soon after application. This test evaluated the delay required between spraying and planting in volcanic ash soil to avoid damage on Douglas-fir, white pine, and ponderosa pine seedlings. Two rates of Tordon 101 were applied in early and late summer. Survival and growth of planted seedlings were not affected by Tordon 101. Picloram concentration found at soil depths of 0-6 and 6-12 inches at time of planting was insufficient to cause injury. Foliar concentrations after one growing season were below detectable limits and resulted only in slight needle curl in Douglas-fir.
KEYW Herbicides, Tordon.

21 AUTH Kidd, F. A., Miller, D. L.
DATE 1983
TITL Swamp Creek herbicide screening - second season results.
PUBL Forest Research Note RN-83-6. Lewiston, ID: Potlatch Corporation. 11 p.
ABST Efficacy of selected rates and timing of application for various herbicides was evaluated for northern Idaho brush species and conifers. Garlon 4, Roundup, Tordon 101, and 2,4-D were aerially applied to twenty-three test plots in 1981. Early foliar (late June) applications resulted in the greatest topkill and cover reduction of brush, but also caused the most defoliation of conifers. Roundup (2 qt ai/acre), Garlon 4 (3 qt ai/acre + 3 qt Diesel adjuvant), and Tordon 101 + 2,4-D (1 gal + 2 lb ai/acre) were all effective for brush control. Late summer applications (late August) were slightly less effective for brush control, but damage to conifers was reduced.
KEYW Herbicides, Garlon, Roundup, Tordon, 2, 4-D.

322 AUTH King, J. P.
DATE 1971
TITL Some proposals for breeding weevil-resistant white pine.
PUBL Paper presented at: International Union of Forest Research Organizations 15th Congressional Proceedings. 9 p.
ABST Breeding a variety of eastern white pine (*Pinus strobus*) that is resistant to attack from the white-pine weevil (*Pissodes strobi*) is made difficult by the relatively small amount of variation in resistance within this species of white pine. This paper suggests interspecific hybridization of *P. strobus* with *P. monticola* and *P. peuce* as a means of increasing the resistance variation and offers some proposals for developing a more effective breeding program.
KEYW Weevil resistance, *Pinus strobus* x *P. monticola*, hybrids, insect resistance.

323 AUTH Kirk, T. K., Highley, T. L.
DATE 1973
TITL Quantitative changes in structural components of conifer woods during decay by white- and brown-rot fungi.
PUBL Phytopathology. 63: 1338-1342.
ABST Quantitative changes in lignin, glucan, mannan, and xylan during decay of five conifer woods by three white-rot and three brown-rot fungi were determined. (Glucan, mannan, and xylan provided estimates of cellulose and the hemicelluloses galactoglucomannan and aragino-4-0-methylglucuronoxylan, respectively.) All the white-rot fungi removed all the major wood components progressively during decay; the brown-rot fungi removed the polysaccharides but not lignin. The white- and brown-rot fungi removed the mannan and usually xylan faster than glucan, but the difference was not as pronounced for the white-rot as for the brown-rot organisms. The brown-rot fungi all had similar effects on the chemical composition of all the woods. In the white-rot type of decay, there was variation in the effects on the chemical composition; this appeared to depend more on the wood being decayed than the fungus involved.

KEYW *Polyporus versicolor, Ganoderma applanatum, Peniophora, Poria monticola, Lensites trabea, Lentinus lepideus,* white rot fungi, brown stain.

324 AUTH Koch, E.
DATE 1926
TITL The future of forest lands in Montana and Idaho.
PUBL Journal of Forestry. 24: 518-532.
ABST The author issues a warning that cutting practices are too intensive to support the present timber industry. He foresees much road building and intensive silviculture.
KEYW Timber production, timber needs, timber depletion.

325 AUTH Koch, E.
DATE 1937
TITL Function of National Forest timber in Idaho white pine region.
PUBL Forestry News Digest. 37(6): 21-22.
ABST The author states that the lumber industry of the Idaho white pine region is largely built on pine, and when the pine is gone the industry is gone. He predicts that at the present rate (1937), the majority of the mills will be shut down within 10 to 12 years due to excess cutting on private lands.
KEYW Lumber supply, sustained yield.

326 AUTH Koch, E., Cunningham, R. N.
DATE 1927
TITL Timber growing and logging practice in the western white pine and larch-fir forests of the Northern Rocky Mountains.
PUBL Bulletin 1494. Washington, DC: U.S. Department of Agriculture, Forest Service. 38 p.
ABST The western white pine type is discussed in terms of its general character, logging practices, fire control, slash disposal, thinning, cutting methods, planting, and disease control. The practicality of growing white pine timber is discussed in terms of growth and yield, and the costs involved in growing the timber. Desirable forest practices are presented throughout the paper.
KEYW Silvicultural methods, white pine type.

327 AUTH Koenigs, J. W.
DATE 1966
TITL Studies of cytochemical localization of specific dehydrogenases in frozen, diseased tissues of *Pinus*.
PUBL American Journal of Botany. 53: 1101-1108.
ABST Intracellular activity of individual dehydrogenases in frozen tissues of *Pinus monticola* and *Cronartium ribicola* was demonstrated by supplying a specific substrate and the appropriate pyridine-nucleotide-linked coenzyme. Freezing broke cell-permeability barriers, releasing endogenous coenzymes and substrates which had produced nonspecific enzymatic reduction of nitro blue tetrazolium by miscellaneous dehydrogenases throughout fresh tissues.
KEYW Cytochemistry, dehydrogenase, diseased tissue, frozen tissue, tetrazolium cytochemistry.

328 AUTH Kotak, E. S.
DATE 1973
TITL Western white pine—an American wood.
PUBL FS-258. Washington, DC: U.S. Department of Agriculture, Forest Service. 6 p.
ABST Western white pine is "king of the pines" in the Inland Empire, that portion of northern Idaho, western Montana, eastern Washington, and interior British Columbia lying between the Pacific Coastal Ranges and the Rocky Mountains. It is generally the tallest, straightest, and most important commercial species within its range. Its wood has been valued, along with the other white pines, for a great many lumber and related products where light color, ease of working with tools, straightness of grain, and fine texture are especially prized. At one time, western white pine was the principal species used for wooden matches. It is now (1973) being used extensively for plywood and pulp.
KEYW Uses.

329 AUTH Krasjina, V. J.
DATE 1955
TITL Transpiration and shade-tolerance of trees.
PUBL Bulletin of the Ecology Society of America. 36(2): 51.
ABST States that *P. monticola* is shade-intolerant in certain humid regions, whereas it may become shade-tolerant in relatively drier areas.
KEYW Transpiration, shade tolerance.

330 AUTH Kriebel, H. B.
DATE 1959
TITL Current research in forest tree improvement at the Ohio Agricultural Experiment Station.
PUBL In: Proceedings, 6th meeting of Canadian Forestry Tree Breeding Committee. 1958. p. q3-q5
ABST Grafting of soft pines on *Pinus strobus* included the following species and cultivars: *P. koraiensis, P. parviflora, P. parviflora pentaphylla, P. flexilis, P. griffithii, P. peuce, P. strobus, P. strobus fastigioata, P. cembra, P. monticola, P. armandii,* and *P. ayacahuite.* Several clones of each species were being propagated. A breeding arboretum was to be started in 1959.

KEYW Grafts on *Pinus strobus*.

AUTH Kriebel, H. B., Fowler, D. P.
DATE 1965
TITL Variability in needle characteristics of soft pine species and hybrids.
PUBL Silvae Genetica. 14: 73-76.
ABST Some needle characters of species and hybrids of soft pines are described, including number of serrulations on the axial margin, position and number of rows of stomata, position of resin canals, number of resin canals, and thickness of hypodermal cell walls. The studies showed that there is more genetic variability within the various taxa than was indicated by earlier investigations. Moreover, certain characters vary with the age of the tree or with the part of the needle that is sampled.
KEYW Needle characteristics, *Pinus monticola* x *P. ayacahuite*, *Pinus monticola* x *P. peuce*, *Pinus monticola* x (*P. peuce* x *strobus*), *Pinus monticola* x *P. strobus*, *Pinus monticola* x *P. griffithii*, hybrids-needle characteristics.

AUTH Kruckeberg, A. R.
DATE 1964
TITL Interrelations between plant distribution and soil type.
PUBL Proceedings, 10th Annual Botanical Congress. p. 13-14.
ABST Describes plant life on serpentines and other ultramafic rocks in northwestern North America. Where ultramafic rocks such as serpentine, peridotite, and dunite outcrop in Oregon, Washington, and British Columbia, the vegetation often contrasts markedly with that on adjacent but different rock types. The *Tsuga heterophylla-Thuja plicata* and the *Pseudotsuga menziesii-Pinus ponderosa* forest types may give way to stunted, sparse stands of *Pseudotsuga menziesii*, *Pinus monticola*, *P. contorta*, and *Juniperus communis*. The response of vegetation to ultramafic rocks takes various forms: (1) dwarfing, lowered abundance, or altitudinal extensions of regional coniferous species; (2) omission of many of circumjacent nonultramafic species (a depauperized flora on ultramafics); (3) widespread discontinuous occurrence on ultramafics of two ferns; (4) "pioneer"-type community with much bare ground; and (5) occurrence of few but distinctive endemic species on some ultramafic outcrops.
KEYW Soil type, distribution.

AUTH Krugman, S. L., Jenkinson, J. L.
DATE 1974
TITL Seeds of woody plants in the United States—*Pinus*.
PUBL Agriculture Handbook 450. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 598-638.
ABST For *Pinus monticola*, the following information is given: Local variations with elevation and site are recognized. Progenies from high-elevation origins grow faster at high elevations than those from low-elevation origins. Seeds from northern Idaho are smaller than those from Washington and California. Other information is contained in several tables.
KEYW Seeds.

334 AUTH Kuijt, J.
DATE 1956
TITL A new record of dwarf mistletoe on lodgepole and western white pine.
PUBL Madroño. 13: 170-172.
ABST A single small tree of western white pine near Horne Lake, Vancouver Island, BC, was found to bear dwarf mistletoe shoots protruding from fusiform to spherical swellings on the branches and main stem. The lodgepole pine overstory was heavily infected with *Arceuthobium campylopodum*.
KEYW Dwarf mistletoe, *Arceuthobium campylopodum*.

335 AUTH Kulhavy, D. L., Chacko, R. J., Partridge, A. D.
DATE 1978
TITL Some decay and disease fungi isolated from western white pine in northern Idaho.
PUBL Plant Disease Reporter. 62(4): 332-336.
ABST Isolations from stems and roots of standing western white pine indicate disease fungi are common throughout the range of this species in northern Idaho. The most common stem pathogens were *Fomes pini*, *Stereum sanguinolentum*, *Armillaria mellea*, and *Polyporus schweinitzii*. The most common root pathogens were *A. mellea*, *P. schweinitzii*, and *Odontia bicolor*. Four species of *Verticicladiella*, *V. wagenerii*, *V. antibiotica*, *V. penicillata*, and *V. abietina*, were isolated from white pine, the latter three for the first time.
KEYW Stem diseases, root diseases.

336 AUTH Kutney, J. P., Eigendorf, G., Swingle, R. B., Knowles, G. D., Rowe, J. W., Nagasampagi, B. A.
DATE 1973
TITL Novel triterpenes from western white pine (*Pinus monticola* Dougl.) bark.
PUBL Letter 33. Pergamon Press, Great Britain Tetrahedron. p. 3115-3118.
ABST After a preliminary investigation of the chemistry of western white pine bark, a more detailed study of the benzene extract was undertaken. A total of 90 terpenoids

were isolated, including 34 triterpenes. These include 24-methylene-cycloartanol, 10 known and 10 new serratanes, and 11 new triterpenes that appear to have a common skeleton. The two major components of this last group are a methoxydiol and a triol which comprise 0.7 and 0.2 percent of the benzene extract, respectively.
KEYW Triterpenes.

337 AUTH Kutney, J. P., Eigendorf, G., Worth, B. R., Rowe, J. W., Conner, A. H., Nagasampagi, B. A.
DATE 1981
TITL New triterpenes from the bark of western white pine (*Pinus monticola* Dougl.).
PUBL Helvetica Chimica Acta. 64(4), No. 111: 1183-1207.
ABST Eleven new triterpenes with the lanostene-type skeleton were isolated from benzene extract of western white pine bark. Their structures were determined mainly on the basis of physical and spectral data.
KEYW Triterpenes.

338 AUTH Lambeth, C. C.
DATE 1980
TITL Juvenile-mature correlations in Pinaceae and implications for early selection.
PUBL Forest Science. 26: 571-580
ABST Juvenile-mature correlations in the literature were analyzed and found to be more predictable than may have been expected by those who have dealt with them. Age-age correlations except those involving very young ages, usually 1 to 3 years, can be estimated with reasonable accuracy by a single regression equation which applies to several species and studies. Applicability of the equation to genetic test situations may be possible. After predicting age-age correlations, optimum selection age was estimated for several economic rotations. These ages for 30- and 40-year economic rotations were 6 and 8 years, respectively, for the conditions specified.
KEYW Age-age correlations, early selection, gain per year.

339 AUTH Landry, P. P.
DATE 1976
TITL Taxinomie tridifferenteille de *Pinus stobus* L. et de *Pinus monticola* Dougl.
PUBL Bulletin of the Botanical Society of France. 123: 47-60.
ABST Up to now, dendrologists have individually given at most one or two neat differences, without overlapping, between *Pinus strobus* and *P. monticola,* giving the impression that these two taxons were perhaps not specifically distinct. The author, after making a review of the extant literature on this subject, compares seven morphological characters and he concludes that four of them are neatly different:the kind of hairiness on the twigs, the number of fertile scales per cm of length of the female cones, and the shape of the cracks on the bark of older trees. It is concluded that the taxons are specifically distinct. A complete taxonomic documentation is given of both species as found in natural habitats, including three subspecific taxons, *P. strobus* var. *prostrata, P. monticola* var. *minima*, and *P. monticola* f. *porphyrocarpa.*
KEYW Taxonomy, morphological characters, *Pinus monticola* var. *minima*, *Pinus monticola* f. *porphyrocoppa.*

340 AUTH Larsen, J. A.
DATE 1918
TITL Comparison of seed testing in sand and in the Jacobsen germinator.
PUBL Journal of Forestry. 18: 690-695.
ABST The author compared germination in sand with germination in the Jacobsen germinator for nine conifer species. Results for *P. monticola* were: percent germination after 32 days - sand 18.5 percent, germinator 22.0 percent; percent per day of most rapid germination - sand 1.2, germinator 2.0; days required for complete germination - sand 200, germinator not completed.
KEYW Seed germination, seed testing, Jacobsen germinator, germinating medium.

341 AUTH Larsen, J. A.
DATE 1918
TITL Growth of western white pine and associated species in northern Idaho.
PUBL Journal of Forestry. 16: 839-840.
ABST Early data from sample plots at Priest River Experimental Forest, ID, are summarized. The most significant fact brought out is the remarkable growth of western white pine, which in this instance adds 1,095 bd ft per acre per year, followed by Douglas-fir at 879 bd ft and ponderosa pine with 745 bd ft. The data show an actual increase of 9.1 percent for white pine, 7.2 for yellow pine, 11.9 for Douglas-fir, and 5.6 percent for larch.
KEYW Annual growth, yield, annual growth comparison, *Larix occidentalis, Pseudotsuga menziesii, Pinus ponderosa.*

342 AUTH Larsen, J. A.
DATE 1921
TITL Germination of seed in the duff under western white pine stands.
PUBL District 1 Applied Forestry Note 22. Missoula, MT: U.S. Department of Agriculture, Forest Service. 3 p.

ABST Conclusions drawn from this study are: (1) The amount of white pine seed stored in the duff is dependent upon the number of white pine trees in the original stand and their seed productive capacity. (2) In old decadent stands of white pine, lesser results must be counted on from seed in the duff than from younger and more thrifty stands. (3) The preservation of the duff layer favors the restocking of white pine. (4) Burning of the duff layer destroys stored seed and eliminates the possibility of restocking except by reseeding or by planting.
KEYW Seed germination, duff, regeneration.

343 AUTH Larsen, J. A.
DATE 1922
TITL Effect of the removal of the virgin white pine stand upon the physical factors of site.
PUBL Ecology. 3: 302-305.
ABST Records kept during July and August showed the following differences between virgin forest stands and clearcut areas: air temperature, 10 degrees warmer in uncut forest at night and 10 degrees cooler during the hot part of the day; soil temperature, 4-5 degrees fluctuation in the clearcut area, only 1 degree in the uncut forest; evaporation is more than twice as great in the open as under timber; soil moisture is lower under timber than in the open. The author concludes that clearcutting renders a site precarious for the establishment of white pine seedlings.
KEYW Air temperature, humidity, soil temperature, soil moisture, clearcut air temperature, closed forest air temperature, clearcut soil temperature, closed forest soil temperature, clearcut soil moisture, closed forest soil moisture.

344 AUTH Larsen, J. A.
DATE 1922
TITL Some characteristics of seeds of coniferous trees from the Pacific Northwest.
PUBL National Nurseryman. 30: 246-249.
ABST Germination tests and observations on the character of seeds of coniferous trees native to Montana and northern Idaho showed that: (1) the seed is liable to serious injury by storage of the cones in wet conditions; (2) the extraction of the seed under temperatures above 120 °F and in such hot and very humid air reduces the viability of the seeds; (3) sterilization to prevent damping-off or bad molding is apt to injure seed of small, thin seed coats; (4) the rate of germination of seeds which ordinarily germinate slowly may be hastened materially by reduction of the impervious seed coat; and (5) coniferous seeds often remain viable in dry storage from 8 to 10 years.
KEYW Seeds, seed characteristics, seed extraction, seed germination, seed storage, delayed germination.

345 AUTH Larsen, J. A.
DATE 1923
TITL Another thought on slash disposal in western white pine stands.
PUBL Applied Forestry Note 36. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 2 p.
ABST Stresses that no one method of slash disposal may be used under all circumstances. Diverse field conditions necessitate different methods. Slash burning in piles, in windrows, broadcast, forced burning, burning in different seasons, at night, and under different climatic conditions have all been tried. The author suggests that man's originality and ingenuity are the greatest needs.
KEYW Slash disposal, slash burning.

346 AUTH Larsen, J. A.
DATE 1923
TITL Association of trees, shrubs, and other vegetation in the northern Idaho forests.
PUBL Ecology. 4: 63-67.
ABST The author classifies the forests of northern Idaho into four altitudinal belts or forest types: western yellow (ponderosa) pine; western larch—Douglas-fir; white pine, cedar, hemlock, and lowland white fir; and subalpine (mountain hemlock, alpine fir, Engelmann spruce, and lodgepole pine). He lists associated vegetation for all but the subalpine type.
KEYW Vegetation classification, habitat type.

347 AUTH Larsen, J. A.
DATE 1924
TITL Natural reproduction on single and double burns in northern Idaho.
PUBL Applied Forestry Note 52. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Natural reproduction after a single burn on three strips was comprised of 44 percent, 36 percent, and 53 percent western white pine. After double burns, only larch and white fir survived at all. It is evident from these data that natural reproduction comes in fairly abundantly after single fires, and only scantily or not at all after a second fire. Results indicate that south and west slopes should be the first to be planted.
KEYW Natural reproduction, single burn, double burn.

348 AUTH Larsen, J. A.
DATE 1924
Some factors affecting reproduction after logging in northern Idaho.
PUBL Agricultural Research. 28: 1149-1157.
ABST Large openings made in the forest cover by clearcutting cause increase in air and soil temperature, evaporation, and moisture deficit, which present unfavorable conditions for reestablishment of moisture-loving species. Furthermore, changed surface conditions resulting from large openings and vegetation on areas completely cleared may defeat natural regeneration altogether. Surfaces of ash and bare mineral soil when loose offer the most favorable conditions for rapid germination and establishment of seedlings provided seed is immediately available, but where overhead or adjacent trees must supply the seed for natural restocking over a period of years, a loose and protected surface such as is provided by needle duff and light vegetation is more favorable. The extremely high surface soil temperatures which occur on cleared and exposed flats and south slopes are injurious to establishment of seedlings of western white pine, cedar, and hemlock, and this explains the general scarcity of these species on sites exposed to sun and wind and the difficulty of restocking these after clearcutting on a large scale. A method of cutting which would provide smaller openings and partial shade or shelter would produce better silvicultural results.
KEYW Reproduction, seed germination, survival, seed beds, moisture, soil temperature aspect, soil.

349 AUTH Larsen, J. A.
DATE 1925
TITL Methods of stimulating germination of western white-pine seed.
PUBL Agricultural Research. 31: 889-899.
ABST The delayed germination of western white pine seed is due to the presence of an impermeable seed coat, not to any inherent physiological characteristics. Four methods to ensure prompt germination are discussed.
KEYW Seed stratification, seed scarification, seed ripening.

350 AUTH Larsen, J. A.
DATE 1925
TITL Natural reproduction after forest fires in northern Idaho.
PUBL Agricultural Research. 30: 1177-1197.
ABST Natural restocking on once and twice-burned areas was studied. Where a single fire destroyed a mature forest, the natural restocking has been prompt, uniform, and complete, with western white pine comprising a substantial portion of the reproduction. Timing of regeneration, storage of seed in the duff, and the influence of the character of the burn on reproduction are all discussed.
KEYW Seed distribution, seed germination, succession, fire.

351 AUTH Larsen, J. A.
DATE 1925
TITL Products from immature white pine stands in Idaho.
PUBL Idaho Forester. 7: 15-16, 45.
ABST A medium thinning in a 1.5-acre plot produced 987 ft^3 (white pine, Douglas-fir, larch, ponderosa, and lodgepole pine), used as mining stulls (24), railroad ties (13), fenceposts (191), mining props (17), fence rails (14), bucket stock (300), and cordwood (9.7 ft^3).
KEYW Products from thinning, thinning.

352 AUTH Larsen, J. A.
DATE 1927
TITL Relation of leaf structure of conifers to light and moisture.
PUBL Ecology. 8: 371-377.
ABST Comparisons of leaf structure of coniferous trees with respect to different requirements for moisture and light are tabulated for several coniferous species.
KEYW Leaf structure, light, moisture, shade tolerance.

353 AUTH Larsen, J. A.
DATE 1929
TITL Fires and forest succession in the Bitterroot Mountains of northern Idaho.
PUBL Ecology. 10: 67-76.
ABST When the cedar-hemlock-grand fir forest in the Bitterroot Mountains is destroyed by fire, the forest returns to its climax composition through a series of associations occurring in regular succession. Forest zones and silvical requirements of the trees are discussed, and their relative requirements for light, moisture, and soil fertility are presented. Principal species found in each major association are listed.
KEYW Plant sociology, succession, fire.

354 AUTH Larsen, J. A.
DATE 1930
TITL Forest types of the Northern Rocky Mountains and their climatic controls.
PUBL Ecology. 11: 631-672.
ABST The natural distribution and chief silvical and climatic characteristics of the natural

forest types of the Northern Rocky Mountains in Montana and Idaho are discussed. The western white pine type is among those described in detail.
KEYW Relative species tolerance, tolerance.

355 AUTH Larsen, J. A.
DATE 1940
TITL Site factor variations and responses in temporary forest types in northern Idaho.
PUBL Ecological Monographs. 10: 1-54.
ABST Air temperature relations show higher daily and seasonal maximums on the southwest aspect with a longer duration of temperatures favorable for growth than at the other points. The minimums of the air temperatures were lowest on the flat both winter and summer and highest on the northeast slope. Soil temperatures reflect and follow the trend of the air temperatures, but diverge far more at the surfaces and in the upper soil stratum than at the lower levels. The southwest aspect is characterized by a shallower snow cover, which is also of shorter duration than on the other sites. The soil moisture reaches more critical minimums and remains at dangerously low points for extended periods in summer, and wind movement and evaporation are more pronounced than elsewhere. The soils on the northeast slope and where the mesic species grow contain a greater clay and silt fraction and higher capillary and other moisture-retaining qualities than those occupied by the xerophytic western yellow (ponderosa) pine. Soils of the more sandy flats which become occupied with larch and Douglas-fir are ordinarily not sufficiently improved in physical properties to favor the growth of western white pine, cedar, and hemlock. Seedlings raised from seed from the different sites expressed, by their germination during the first two seasons and by their survival and height growth to the end of the fifth year, a conformity to the already existing forest trees which had seeded in after the forest of 60 years ago.
KEYW Site factor variation, planting tests, climate, edaphic factors, seedling survival.

356 Deleted.

357 AUTH Larsen, J. A., Lowdermilk, W. C.
DATE 1924
TITL Slash disposal in western white pine forests in Idaho.
PUBL Circular 292. Washington, DC: U.S. Department of Agriculture. 20 p.
ABST Broadcast burning in the white pine type does not meet the requirements of fire protection or of silviculture. The method of piling and burning is valuable in reducing the fire hazard, while preserving favorable site conditions.
KEYW Broadcast burning, fire protection, piling and burning, site conditions.

358 AUTH Larsen, J. A., Stump, W. G.
DATE 1939
TITL Some experiments with fertilizers for evergreen seedlings.
PUBL Journal of Science. Ames, IA: Iowa State College; 13: 293-305.
ABST This paper presents the results of fertilizer tests conducted on several species of nursery stock including white pine. The same reagents are noted to produce different results in the various species. In general, the use of nitrogen fertilizers increased top growth; those containing phosphorus increased root development. In the nursery, a combination of fertilizers containing N, P, and K was usually more effective than a single treatment of only one element. In the greenhouse tests, single elements proved more effective.
KEYW Fertilizer, root growth, top growth, seedlings, greenhouse, nursery.

359 AUTH Leaphart, C. D.
DATE 1956
TITL Physiological studies of some fungi associated with pole blight of western white pine.
PUBL Mycologia. 48(1): 25-40.
ABST Physiological requirements are reported for five fungal isolates commonly associated with pole blight of western white pine. Four of the isolates belonged to the genus *Leptographium;* the fifth was *Ceratocystis pilifera.* Parameters studied included temperature, pH, and vitamin requirements, and carbohydrate and nitrogen utilization.
KEYW *Leptographium, Ceratocystis pilifera,* pole blight.

360 AUTH Leaphart, C. D.
DATE 1958
TITL Pole blight—how it may influence western white pine management in light of current knowledge.
PUBL Journal of Forestry. 56: 746-751.

ABST Summarizes current knowledge of pole blight. Indicates that no specific cause has yet been determined for the disease, except perhaps climatic conditions. No fungus, virus, or primary insect has been identified as the cause of rootlet deterioration present in blighted trees.

KEYW Pole blight, rootlet deterioration, climate.

361 AUTH Leaphart, C. D.

DATE 1958

TITL Root characteristics of western white pine and associated tree species in a stand affected with pole blight of white pine.

PUBL Research Paper 52. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.

ABST Data were collected on the Priest River Experimental Forest in northern Idaho from a 1-acre area in a white pine stand where pole blight was first observed in 1941. Data include: species stand table showing number of stems and basal area per acre and percentage of trees in the dominant and codominant crown classes; ratio of rootlet length to length of parent lateral root, root tips per rootlet; and average rootlet and root tip mortality of tree species. The authors conclude that the climax species appear to be well adapted to compete for available moisture in the pole blight area under study. Western redcedar may be the most effective competitor. Climax species' roots of all diameters with their attached rootlets occupy the soil area much more completely than the subclimax group. White pine must transport water for greater distance since it has a greater structural root length than the other species except possibly grand fir and spruce. This study suggests that if other factors were constant and equal for all species, western white pine, because of its less profuse fine root system, would not be able to compete as efficiently for water and mineral uptake as other species within pole blight areas.

KEYW Root characteristics, pole blight, lateral root length, root tips, root mortality, root distribution, root length.

362 AUTH Leaphart, C. D.

DATE 1959

TITL Drought damage to western white pine and associated tree species.

PUBL Plant Disease Reporter. 43: 809-813.

ABST An unusually dry summer in 1958, characterized by abnormally high temperatures, damaged western white pine, western larch, grand fir, and lodgepole pine in an area in northeastern Washington and northern Idaho. Damage ranged from foliage wilting to death of trees, and affected trees from 3 to 25 ft tall.

KEYW Drought, drought injury, *Larix occidentalis, Abies grandis, Pinus contorta*.

363 AUTH Leaphart, C. D., Copeland, O. L., Jr.

DATE 1957

TITL Root and soil relationships associated with the pole blight disease of western white pine.

PUBL Soil Science Society of America Proceedings. 21(5): 551-554.

ABST Root density and mortality were determined in 30 healthy western white pine stands ranging from 20 to 160 years old. Similar determinations were made in 16 stands of the 60- to 80-year age class affected by pole blight, a disease of unknown cause. Various physical soil characteristics were measured in 26 healthy and diseased stands in conjunction with the root study. Both rootlet mortality and density in the upper 1 ft of soil are significantly correlated with the available water storage capacity in the soil depth occupied by a major portion of the root system. The available water storage capacity is dependent upon effective soil depth. As the severity of pole blight increases, rootlet mortality increases and available water storage capacity and effective soil depth become less. These results indicate an edaphic relationship to the pole blight disease.

KEYW Pole blight, soil.

364 AUTH Leaphart, C. D., Copeland, O. L., Jr., Graham, D. P.

DATE 1957

TITL Pole blight of western white pine.

PUBL Forest Pest Leaflet 16. Washington, DC: U.S. Department of Agriculture, Forest Service. 4 p.

ABST Gives a general description of pole blight including its distribution, importance, and symptoms. No cause or method of control has been discovered.

KEYW Pole blight.

365 AUTH Leaphart, C. D., Foiles, M. W.

DATE 1972

TITL Effects of removing pole-blighted western white pine trees on growth and development of a mixed conifer stand.

PUBL Research Note INT-161. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.

ABST A mixed conifer stand, in which western white pine was infected with the pole blight disease, was treated by removing either (a) all blighted trees, or (b) merchantable

blighted trees. Neither treatment significantly altered the development of pole blight in the residual stand for 17 years following the cutting. The Douglas-fir component suffered heavy mortality, caused mostly by *Poria weirii* root rot; therefore, it had negative net growth for the period. Western redcedar, the predominant understory conifer, responded well to release and accounted for much of the basal area and cubic volume increment.

KEYW Pole blight, cleaning stand, *Pseudotsuga menziesii, Poria weirii, Thuja plicata.*

366 AUTH Leaphart, C. D., Gill, L. S.

DATE 1955

TITL Lesions associated with pole blight of western white pine.

PUBL Forest Science. 1(3): 232-239.

ABST This study indicates that reduced radial growth precedes both crown decline and lesion development in white pine afflicted with pole blight. Lesions are apparently not directly responsible for the progressive decline of diseased trees.

KEYW Pole blight, lesions, crown symptoms, radial growth.

367 AUTH Leaphart, C. D., Gill, L. S.

DATE 1959

TITL Effects of inoculations with *Leptographium* spp. on western white pine.

PUBL Phytopathology. 49: 350-353.

ABST Seven isolates of *Leptographium* were used in several series of inoculations on healthy western white pine trees. About 2,300 inoculations, involving different techniques of wounding and several types of inoculum, were made on different portions of the roots and stems of 321 trees during a 3-year period. All isolates caused some degree of cambial necrosis, but differences in virulence were observed. Definite callusing developed around the edges of nearly all lesions within 1 year of inoculations; fewer than three of the positive inoculations were still active 3 years later. The study suggests that: (1) the potential of this fungus to cause damage in healthy white pine trees is inversely proportionate to the tree's ability to callus diseased tissue; (2) the fungus contributes to the deterioration of the structural root systems of pole-blight-affected stands; and (3) the virulence of the form of *Leptographium* present in a diseased tree may be associated with both the lesion development pattern on the tree and that tree's rate of decline.

KEYW *Leptographium*, cambial necrosis, virulence, artificial inoculation, roots.

368 AUTH Leaphart, C. D., Hungerford, R. D., Johnson, H. E.

DATE 1972

TITL Stem deformities in young trees caused by snowpack and its movement.

PUBL Research Note INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.

ABST After felling and burning, 4-year-old *Pinus monticola* seedlings were planted on north-facing slopes (mean slope 50 percent) at 3,660 to 4,560 ft altitude in northern Idaho in 1959. Subsequent natural regeneration resulted in mixed conifer stands with a mean height of 4.0-4.5 ft in 1968. In a sample of 410 trees (76 percent of which were deformed), six classes of stem deformity were observed, the most common of which was butt sweep. Virtually all the deformities originated within 5 ft of the ground and are attributed to the effects of snow load or movements of the snowpack; many of the taller trees had two or more deformities, and similar deformities were also observed in 40- to 80-year-old stands in the region. The results of the study indicate that the fastest growing species (*P. monticola* and *Larix occidentalis*) are least likely to suffer multiple deformity.

KEYW Injury, snow, stem form, crook, sweep.

369 AUTH Leaphart, C. D., Johnson, H. E.

DATE 1973

TITL Pole blight: also a disease of western white pine plantations.

PUBL Plant Disease Reporter. 57: 948-951.

ABST The pole blight disease of western white pine results from a complex interaction of physiologically related factors. The disease had been found previously only in natural stands of its host between 35 and 150 years old. The authors found it for the first time in a plantation (34 years old since planting). Data suggest that the disease had started by the time the plantation was 22 years old. The implications of this finding in relation to management of white pine are also discussed.

KEYW Pole blight, plantations.

370 AUTH Leaphart, C. D., Stage, A. R.

DATE 1971

TITL Climate: a factor in the origin of the pole blight disease of *Pinus monticola* Dougl.

PUBL Ecology. 52: 229-239.

ABST Measurements of cores or disc samples representing slightly more than 76,000 annual rings from 336 western white pine trees were

compiled to obtain a set of deviations from normal growth of healthy trees that would express the response of these trees to variation in the environment during the last 280 years. Their growth was demonstrated to be a function of temperature and available moisture for the period of climatic record from 1912 to 1958. Extrapolating the relation of growth to weather to the long tree ring record of western white pine, we find that the period 1916-40 represents the most adverse growth conditions with regard to intensity and duration in the last 280 years. This drought, superimposed on sites having severe moisture-stress characteristics, triggered the chain of events which ultimately resulted in pole blight. If the unfavorable conditions for growth during 1916-40 do not represent a shift to a new climatic mean and if western white pine is regenerated only on sites with low moisture-stress characteristics, the probability is high that pole blight will not reoccur for many centuries in stands regenerated from this date on.

KEYW Climate, pole blight, tree rings.

371 AUTH Leiberg, J. B.
DATE 1897
TITL General report on a botanical survey of the Coeur d'Alene Mountains in Idaho during the summer of 1895.
PUBL Contributions of the U.S. National Herbarium. 5(1): 85.
ABST An early botanical survey of northern Idaho. The author describes the topography, drainages, climate, mineral deposits, agricultural capacity, grazing lands, water supply, forest resources, forest zones, and forest problems—insects, fire, and man. Many of the major habitat types are described. He puts the vegetation into four units: yellow pine, white pine, subalpine fir, and white-barked pine.
KEYW Botanical survey, *Pinus ponderosa, Pinus murrayana, Pinus albicaulis, Picea engelmannii, Abies concolor, Abies lasiocarpa, Larix occidentalis, Pseudotsuga menziesii, Thuja plicata, Tsuga pattoniana, Tsuga mertensiana, Taxus brevifola, Juniperus virginiana.*

372 AUTH Leiberg, J. B.
DATE 1899
TITL Present condition of the forested areas in northern Idaho outside the limits of the Priest River Forest Reserve and north of the Clearwater River.
PUBL U.S. Geological Survey 19th Annual Report. p. 373-386.
ABST The amount of acres, standing board feet, and the amount of timber destroyed by fire during the previous 38 years is tabulated for Idaho north of the Clearwater River.
KEYW Acres white pine, board feet standing timber, board feet destroyed by fire.

373 AUTH Leiberg, J. B.
DATE 1899
TITL The Priest River Forest Reserve.
PUBL U.S. Geological Survey 19th Annual Report. p. 217-252.
ABST A report of the Priest River area: topography, water supply, soil, forest conditions, aspect of forest, amount of available timber, soundness of timber, means of transportation of lumber, local demand for lumber, timber cutting, present condition of the forest fires, effect of fires on reproduction, agricultural land, mineral resources, and lists of species.
KEYW Priest River Experimental Forest, history.

374 AUTH Lemn, A. J., Klomparens, W., Moss, V. D.
DATE 1960
TITL Translocation and persistence of cycloheximide (acti-dione) in white pines.
PUBL Forest Science. 6: 306-314.
ABST The antifungal antibiotic cycloheximide (acti-dione) is absorbed by, persists in, and is translocated upward in pole-size western white pine. The antibiotic persists for at least 2 years in the trunk bark of western white pine treated by the basal stem method. Cycloheximide was applied only to the lower trunk area and later recovered from needles of unsprayed branches. Movement was through the water-conducting elements, for the antibiotic could be detected in xylem tissue both at and above the site of application but was never detected in bark (phloem) tissue above the treated area of the trunk. Cycloheximide was also found to be translocated to needles on untreated branches of eastern white pine.
KEYW Cycloheximide, acti-dione, persistence—antibiotics.

375 AUTH Liev, P. J., Kelsey, R. G., Shafizadeh, F.
DATE 1979
TITL Some chemical characteristics of green and dead lodgepole pine and western white pine.
PUBL Research Note INT-256. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST The chemical components and combustion characteristics of dead and live lodgepole pine and western white pine were determined. Except for small variations, the chemical composition and burning characteristics of sound dead wood were nearly identical to the corresponding live wood for

both species. Therefore, dead wood could be utilized as a source of chemicals, as fuel, and as a substitute for live timber in the manufacture of wood products.
KEYW Chemical components, combustion characteristics, dead trees, utilization of dead trees.

376 AUTH Lindstedt, G.
DATE 1949
TITL Constituents of pine heartwood.
PUBL Acta Chemica Scandinavica. 3: 1147-1152.
ABST The following constituents have been isolated from the heartwood of *Pinus monticola*: pinitol, l-arabinose, chrysin (5,7-di-hydroxyflavone), strobopinin (probably a c-methyl dihydroxyflavanone), tectochrysin (5-hydroxy-7-methoxyflavone), and pinosylvin monomethyl ether.
KEYW Heartwood constituents, chemical composition.

377 AUTH Loewenstein, H., Pitkin, F. H.
DATE 1963
TITL Response of grand fir and western white pine to fertilizer applications.
PUBL Northwest Science. 37: 23-30.
ABST Highly significant height growth increases developed during the second growing season after treatment. Compared with elongation prior to fertilization, these increases ranged as high as 286 percent for grand fir and 187 percent for white pine.
KEYW Fertilizer, plantation growth.

378 AUTH Lowdermilk, W. C.
DATE 1921
TITL The problem of the unmerchantable trees in the white pine stands.
PUBL District 1 Applied Forestry Note 13. Missoula, MT: U.S. Department of Agriculture, Forest Service. 4 p.
ABST Broadcast burning any cutover areas bearing a stand of unmerchantable trees, whether on land listed as agricultural or nonagricultural, cannot be considered a satisfactory measure from the protection viewpoint. The felling of such trees previous to burning is necessary.
KEYW Unmerchantable trees, broadcast burning.

379 AUTH Lowdermilk, W. C.
DATE 1921
TITL Seed.
PUBL District 1 Applied Forestry Note 12. Missoula, MT: U.S. Department of Agriculture, Forest Service. 2 p.
ABST The following seed characteristics are given for western white pine: 24,000-31,000 seeds per lb, 2 years to mature, 60 percent nursery germination, seeds ripen in August and are shed in September, youngest cone bearing age in nature is 15 to 20 years.
KEYW Seed germination, seed production, seed maturity, cone bearing age.

380 AUTH Lowdermilk, W. C.
DATE 1922
TITL An outline of slash disposal practice in District One.
PUBL District 1 Applied Forestry Note 32. Missoula, MT: U.S. Department of Agriculture, Forest Service. 5 p.
ABST Slash disposal is practiced for two reasons: (1) to reduce fire hazard, and (2) to favor natural restocking of the logged-off tract. Specifications are given for slash disposal for the following types: western yellow pine, lodgepole pine, western larch, Douglas-fir, and western white pine. Information is also given on 1922 costs (western white pine, \$0.60 to \$1.25 per thousand bd ft) and rate of decomposition (western white pine, 10 to 15 years).
KEYW Slash disposal, fire hazard.

381 AUTH Lutz, H. J., Chandler, R. F.
DATE 1951
TITL Observations on litter fall and foliage nutrient content of some Pacific Northwest tree species.
PUBL Journal of Forestry. 49(12): 914-915.
ABST Preliminary observations are presented for annual litter fall and foliage nutrient content of ten Pacific Northwest tree species. Species are compared for the relative amounts of nitrogen, phosphorus, potassium, calcium, and magnesium contained within their foliage. The soil-building potential of red alder and western redcedar are emphasized.
KEYW Annual litter fall, foliage nutrient content, nitrogen, phosphorus, potassium, calcium, magnesium, soil pH.

382 AUTH Lynch, D. W., Schumacher, F. X.
DATE 1941
TITL Concerning the dispersion of natural regeneration.
PUBL Journal of Forestry. 39: 49-51.
ABST Although individual seedlings of natural reproduction are not distributed at random on cutover areas, analysis of recently published data from the western white pine type shows a remarkable consistency in the proportion of stocked quadrats of different size.
KEYW Natural regeneration, regeneration dispersal.

383 AUTH Machanicek, J.
DATE 1967

TITL Quality determination of seeds with delayed germination by the viability of their embryos.
PUBL Communications Instituti Forestalis Cechosloveniae. 5: 89-97.
ABST Tests sponsored by the International Seed Testing Association were conducted to compare prescribed methods of viability determination with the method of germinating extirpated embryos. Results showed that (1) the germination test is not suitable for seed with shorter or longer seed dormancy, (2) biochemical test by staining with tetrazolium provides a rapid, reliable, and easily repeatable evaluation of seed quality, (3) germinating extirpated embryos appears to be convenient only for dormant seed.
KEYW Seed quality, delayed germination, embryo viability, tetrazolium staining.

384 AUTH Mack, R. N.
DATE 1971
TITL Pollen size variation in some western North American pines as related to fossil pollen identification.
PUBL Northwest Science. 45: 257-269.
ABST Discusses methods of differentiating fossil pollens of *Pinus ponderosa, P. monticola, P. flexilis*, and *P. albicaulis*.
KEYW Pollen size, fossil pollen identification, corpus breadth, size frequency distribution.

385 AUTH Mann, W. F., Jr., Musselman, L. J.
DATE 1979
TITL *Senna seymeria* parasitizes western conifers.
PUBL Economic Botany. 33: 338-339.
ABST Describes the growth of *Senna seymeria*, a higher plant (Scrophulariaceae) hemiparasite of conifers and hardwood tree species.
KEYW *Senna seymeria*, parasite.

386 AUTH Manzos, A. M.
DATE 1960
TITL Studying the pH of pollen of tree and shrub species.
PUBL Lesno ZH Arhangelisk. 3(4): 34-37.
ABST Tables show the pH at three stages during the postembryonic development of pollen (bud swelling, opening, and flowering) and also of mature pollen at intervals during storage in a desiccater at 2 °C. It was concluded that pH 4.7-7 indicated viable, whereas pH 7.4-8 indicated nonviable pollen.
KEYW Pollen, pH.

387 AUTH Marshall, R.
DATE 1927
TITL Influence of precipitation cycles on forestry.
PUBL Journal of Forestry. 25: 415-429.
ABST The climate of northern Idaho from 1675-1925, as revealed by stumps of western white pine trees, has exhibited distinct wet and dry periods varying from 20 to 40 years. The 20 years since the Forest Service was created appear to be the driest score of years in $2^1/_2$ centuries. Such cycles have a vital bearing on the practice of forestry.
KEYW Precipitation cycles, tree growth, fire protection, age class, growth curves, climate stand origin, growth and yield.

388 AUTH Marshall, R.
DATE 1928
TITL The life history of some western white pine stands on the Kaniksu National Forest.
PUBL Northwest Science. 2: 48-53.
ABST The paper presents detailed forest biographies of a few trees on the Kaniksu National Forest based on their annual rings. The effects of repeated fires, insects, and site are discussed briefly, and tables are given for age distribution in an all-aged stand, a several-aged stand, a river bottom white pine stand, and a two-aged stand for all species within each stand.
KEYW Life history, all-aged stand, several-aged stand, river bottom stand, two-aged stand, fire, insects, age class, fire history.

389 AUTH Marshall, R.
DATE 1928
TITL Natural reproduction in the western white pine type: progress report summarizing investigations to date.
PUBL RS-MR-102. Missoula, MT: U.S. Departmen of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 72 p.
ABST Reports on Zon's (1915) study and his conclusion that 98 percent of all seed was produced on dominant and codominant trees ir 1911, commenting that later observations bear out Zon's findings (in that only occasional intermediate western white pines bea cones and no records of cones on suppresse trees exist). Notes on mechanical injury anc resulting flower induction in girdled hemlo included. Out of 322 trees of eight species, the only ones on area with good seed crops (1.25 years after girdling) were seven of 16 girdled hemlocks. An experiment in torch-girdling of western white pine for seed production was set up following inconclusi data of effect of 1926 fire injuries on cone production. Four groups of three trees wer girdled by slow torch at Priest River Experimental Forest, but squirrels cut cones 2 day before tallying of yield.
KEYW Seed germination, intensity of burn, dispersal, wind velocity, wind firmness, fire

resistance, aspect, precipitation, temperature, *Larix occidentalis, Tsuga heterophylla, Thuja plicata, Pseudotsuga menziesii, Abies concolor.*

390 AUTH Marshall, R.
DATE 1931
TITL An experimental study of the water relations of seedling conifers with special reference to wilting.
PUBL Ecological Monographs. 1: 37-98.
ABST Water content of seedlings was measured for several species. Data were also taken on the decreasing water content as drying went on. Data were taken on the initial water-supplying power of the soil, as related to wilting and to the critical water content of the seedling tops.
KEYW Plant tissue water content.

391 AUTH Marshall, R., Averill, C.
DATE 1928
TITL Soil alkalinity on recent burns.
PUBL Ecology. 9: 533.
ABST The pH value in burned over areas ranged from 6.5 to 8.0. It was suggested that the alkalinity may contribute to the scarcity of reproduction during the first 2 or 3 years following large fires.
KEYW Soil alkalinity, fire, reproduction and soil alkalinity.

392 AUTH Martin, J. S., Bray, M. W.
DATE 1940
TITL Sulphate pulping of western white pine (*Pinus monticola*).
PUBL Paper Trade Journal. 3: 35-38. [Tappi. 3: 309-312.]
ABST The pulping qualities of western white pine were studied. In general, this species is readily reduced by the sulfate process for the production of strong and bleachable pulps of comparatively high yield and fairly satisfactory physical properties. While some of the strength properties of the pulps are slightly inferior to the average commercial product, the fibers possess excellent tensile strength and good felting quality.
KEYW Sulfate pulping, pulping, chemical analysis-pulpwood.

393 AUTH Martin, N. E.
DATE 1976
TITL Changes in amounts of soluble sugars in western white pine tissues in response to season and blister rust.
PUBL Proceedings, American Phytopathological Society. 3: 318.
ABST Samples of current, 1-, and 2-year needles were randomly collected from crowns of 12- to 16-year-old western white pines in the fall, spring, and summer. Trees with a girdling bole canker (about 50 percent of circumference) were compared with rust-free trees. Needle ages and seasons were responsible for quantity differences in all sugars. In all needle ages, raffinose was reduced to a trace, and stachyose disappeared in seasons of rapid growth. Bole infections did not affect needle sugars. Bark samples from bole cankers and noninfected bark from the same and from different trees were analyzed for soluble sugars and compared. Aecia-producing areas of cankers showed a depletion of each sugar in the season prior to spore production, but resumed the pattern found for other invaded and noninvaded samples in other seasons. All bark areas were identical in kinds of sugars found within each season.
KEYW Blister rust canker, fructose, glucose, sucrose, raffinose, stachyose, sugars, seasonal variation.

394 AUTH Mason, D. T.
DATE 1914
TITL Management of western white pine.
PUBL Society of American Foresters Proceedings. 9: 59-68.
ABST Some overall management guidelines for western white pine were given. From these guidelines, a sample marking plan for the Lolo Creek area on the Clearwater National Forest was shown.
KEYW Management, seed germination, silviculture, marking, slash disposal, species control.

395 AUTH Matsui, Z., Inoue, M.
DATE 1959
TITL The classification and ecological study of soft pine and its species planted in Hokkaido.
PUBL In: Annual Report, Hokkaido Forest Experiment Station, Japan. p. 17-26.
ABST Compares soft pines species native and exotic to Japan. Lists *P. monticola* as one of the best planting trees in the mild temperate zone of Japan, but not for the climates with colder winters.
KEYW Ecology, Japan.

396 AUTH Matzke, E. B., Hulbarn, R. L.
DATE 1942
TITL An analysis of the wood of the three commercial species of white pine.
PUBL Bulletin of the Torrey Botanical Club. 69(8): 573-582.
ABST The pits of ray parenchyma cells in contact with tracheids are described in detail for the three commercial white pine species: *Pinus strobus, P. lambertiana,* and *P. monticola.* In all features, both gross and microscopic,

P. monticola is intermediate between the other two, this conforming with the natural distributions.
KEYW Ray parenchyma pits, tracheid radial walls, ray crossing.

397 AUTH McCauley, K. J., Cook, S. A.
DATE 1980
TITL *Phellinus weirii* infestation of two mountain hemlock forests in the Oregon Cascades.
PUBL Forest Science. 26: 23-29.
ABST Root rot by *Phellinus weirii* was studied in two coniferous stands at 1,650 m elevation in central Oregon. The fungus forms circular areas that are rather devoid of trees at their margins and occupied by successively older vegetation centripetally. Number, species, age, and circumference at breast height of trees were obtained in transects of three infection centers per stand. Some trees escape death or are killed slowly. These "resistant" trees were discriminated by size and age from adjacent regrowth trees.
KEYW Root rot, *Phellinus weirii.*

398 AUTH McDonald, G. I., Hoff, R. J.
DATE 1969
TITL Effect of rooting mediums and hormone application on rooting of western white pine needle fascicles.
PUBL Research Note INT-101. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST Two treatments, hormone application and a medium containing forest soil, produced equal but independent rooting responses in needle bundles obtained from 2-year-old western white pine (*Pinus monticola*) seedlings. Apparent sources of variation in rooting response are discussed.
KEYW Rooting mediums, hormone application, rooting needle fascicles, Rootone.

399 AUTH McDonald, G. I., Hoff, R. J.
DATE 1970
TITL Resistance to *Cronartium ribicola* in *Pinus monticola*: early shedding of infected needles.
PUBL Research Note INT-124. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST Detailed analysis of symptom history provided information on the nature of resistance to *Cronartium ribicola*. In *Pinus monticola* seedlings, two independent and sequential resistance factors appeared to be operative in seedling populations obtained from phenotypically resistant parents, but only one of these factors was present in seedling populations derived from phenotypically susceptible parents.
KEYW Blister rust, rust resistance.

400 AUTH McHarg, C. K.
DATE 1923
TITL The practice of forestry on the Coeur d' Alene National Forest.
PUBL Idaho Forester. 5: 9-13.
ABST The author discusses forest management on the Coeur d'Alene National Forest. The topographic situation and resources are presented. He presents his view on working circles, regulations of cuts, problems with inferior species, forest sanitation, and planting.
KEYW Forest resource, age class, working circle, forest sanitation, slash disposal, planting.

401 AUTH McHarg, C. K., Kittredge, J., Preston, J. F.
DATE 1917
TITL Developments in the marking of western white pine (*Pinus monticola*) in northern Idaho.
PUBL Journal of Forestry. 15: 871-885.
ABST Discusses scientific background and management decisions involved in new marking rules for western white pine and gives the rules for the Coeur d'Alene National Forest.
KEYW Marking rules.

402 AUTH McKeever, D. G.
DATE 1942
TITL Direct seeding of western white pine using poisons for rodent control.
PUBL Research Note 18. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 6 p.
ABST Four areas, 11, 20, 50, and 97 acres in size, all on selected good sites in northern Idaho, have been direct-seeded with western white pine using a poisoning method for rodent control developed by the Fish and Wildlife Service. Third-year survivals of seedlings on the 11- and 50-acre areas, seeded in late October 1939, was 67 percent, and first-year survival on 97 acres seeded in October 1940 was 61 percent. The promising results from these tests indicate that large-scale sowings of this species on the better sites can be a practical and economical method of establishing reproduction.
KEYW Direct seeding.

403 AUTH McKenzie, H. L.
DATE 1942
TITL New species of pine-infesting Margarodidae from California and southwestern United

States (Homoptera: Coccoidea: Margarodidae).
PUBL Microentomology. 7(1): 1-24.
ABST Five new species belonging to two new genera of the family Margarodidae are described. The two new genera are *Pityococcus* and *Desmococcus*. Descriptions of the new species are presented along with pen and ink drawings and a key.
KEYW Margarodidae, *Matsucoccus, Pityococcus, Desmococcus,* pine-infesting.

4 AUTH McMinn, R. G.
DATE 1955
TITL Studies on the root systems of healthy and pole blight affected white pine (*Pinus monticola* Dougl.).
PUBL Unpublished Report. Victoria, BC: Canadian Department of Agriculture, Forest Biology, Division of Forest Biology Laboratory. 31 p.
ABST The root systems of a healthy and an unhealthy white pine were excavated for comparison. The unhealthy tree, which exhibited typical pole blight crown symptoms, was found to have considerable mortality in the smaller structural roots and a greatly reduced absorptive system. Root mortality in the adjacent healthy tree was slight. The degree of root deterioration in the pole-blight-affected tree appeared sufficient to account for the crown symptoms recorded.
KEYW Pole blight, pole blight root systems, needle number, pole blight crown class, mycorrhiza, rootlet types, *Phytophthora cinnanomi.*

5 AUTH McMinn, R. G.
DATE 1959
TITL A study of the relationship between pole blight and rooting characteristics of *Pinus monticola* Dougl.
PUBL In: 9th International Botanical Congress Proceedings. 2: 244.
ABST The root systems of thirty-five pole-sized *Pinus monticola* were excavated hydraulically. Analysis revealed that trees showing advanced decline symptoms in their crowns had serious root deterioration, particularly in their absorbing elements. Certain rooting characteristics seem to predispose this species to decline.
KEYW Pole blight, rooting characteristics, root deterioration.

6 AUTH McMinn, R. G.
DATE 1963
TITL Die mycorrhiza von *Pinus monticola* und die "pole-blight"-krankheit.
PUBL In: Mykorrhiza Proceedings, International Mykorrhiza Symposium. [Weimar, 1960], Gustav Fischer Jena. p. 257-260.
ABST The root systems of healthy and pole-blight-affected *Pinus monticola* were excavated hydraulically to determine whether root condition was correlated with degree of crown symptoms. The different forms of mycorrhizal short rootlets encountered were described. Most mycorrhizal rootlets in affected trees were poorly developed and the abundance of living rootlets was less than on healthy trees.
KEYW Root systems, mycorrhiza, pole blight.

407 AUTH McMinn, R. G.
DATE 1965
TITL Further observations on pole blight of white pine.
PUBL Canadian Department of Agricultural Science Service Bi-monthly Progress Report. 21(6): 3.
ABST Pole blight of western white pine is thought to have been initiated by a series of dry, hot summers which may have begun as early as 1917 and continued until the mid-1940's. Most of the affected trees examined in British Columbia were on noticeably podzolized soils, characteristic of the interior western hemlock zone. Pine stands in areas with relatively dry climates near the margin of the hemlock zone were rarely affected. The relatively favorable soil fertility of the weakly podzolized soils of these areas may have been more effective in promoting resistance to pole blight than drought was in causing the disease. Pole blight was also rare among pine growing toward the upper altitudinal limit of the species in the transition between the hemlock zone and the Engelmann spruce-subalpine fir zone. A significant characteristic of the sites on which pole blight occurred seems to be their ability, when appropriately stocked, to support rapid growth of pine during the early pole stage in normal and moist years.
KEYW Pole blight, British Columbia.

408 AUTH McMinn, R. G., Molnar, A. C.
DATE 1959
TITL Further observations on pole blight and climate.
PUBL Canadian Department of Agriculture Science Service Bi-monthly Progress Report. 15(1): 2-3.
ABST Observations on permanent sample plots have indicated that in the past few years there has been some improvement in the pole blight condition of western white pine. The coincidence of pole blight with the hot, dry part of a climatic cycle supports the hypothesis that this disease is related to the

occurrence of such conditions. This view is further corroborated by the fact that a reduced rate of symptom intensification and recovery trend in some trees was preceded and accompanied by cooler, moister summers.

KEYW Pole blight, climate.

409 AUTH McMullen, L. H., Atkins, M. D.
DATE 1959
TITL Life history and habits of *Scolytus tsugae* (Swaine) (Coleoptera: Scolytidae) in the interior of British Columbia.
PUBL Canadian Entomologist. 91: 416-426.
ABST The results of a study of the life history and habits of *Scolytus tsugae* (Swaine), made near Lumby and Lac la Hache, BC, indicate that the beetle in the interior of the province has a 1-year life cycle with one brood per year. The beetle overwinters in the larval stage, chiefly in the fourth instar. Although there has been some doubt that this species normally attacks *Pinus monticola*, cage studies indicate that it is probably a preferred host.
KEYW *Scolytus tsugae*.

410 AUTH Metcalf, M. E.
DATE 1952
TITL Lumber production approaches all-time record for Northern Rocky Mountain Region.
PUBL Research Note 103. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Western white pine lumber production in 1950 in the Northern Region of the U.S. Forest Service was 343,335,000 bd ft (20 percent of total).
KEYW Production lumber.

411 AUTH Millar, F. G.
DATE 1923
TITL The forestry situation in north Idaho.
PUBL Idaho Forester. 5: 19-22.
ABST Apprises the current timber situation in northern Idaho and outlines essentials of a "State forest policy" suggested for enactment by the legislature
KEYW Timber cut, lumbering, merchantable timber, restocking, forest policy.

412 AUTH Miller, D. L.
DATE 1978
TITL Lights and container size influence greenhouse growth of conifers.
PUBL Forest Technical Paper TP-78-4. Lewiston, ID: Potlatch Corporation. 10 p.
ABST White pine, Douglas-fir, and ponderosa pine were grown in size 2, 4, 7, and 8 containers under photoperiod lights, growth lights, and without supplemental lighting. At the end of the growth cycle, the seedlings were measured for height, caliper, shoot/root ratio, branching, and secondary needles. Photoperiod lights and the 4-cubic-inch container produced optimum growth of Douglas-fir and white pine. Ponderosa pine grew satisfactorily in the 8-cubic-inch container without supplemental lighting.
KEYW Artificial lights, containers for seedlings.

413 AUTH Miller, D. L.
DATE 1981
TITL Can we fall plant white pine?
PUBL Forest Research Note RN-81-6. Lewiston, ID: Potlatch Corporation. 7 p.
ABST Between 1977 and 1980 containerized white pine seedlings were planted on 12 sites during fall and spring planting seasons. First-, second-, and third-year data indicate that there is little difference in survival between fall- and spring-planted seedlings. Height growth was significantly less for fall plantings.
KEYW Fall planting, planting survival.

414 AUTH Miller, D. L.
DATE 1981
TITL The effects of Roundup herbicide on northern Idaho conifers and shrub species.
PUBL Forest Technical Paper TP-81-2. Lewiston, ID: Potlatch Corporation. 13 p.
ABST One, 2, and 3 quarts of Roundup herbicide in 10 gal aqueous solution per acre were aerially applied to six north Idaho test plots in early August 1978. The 1- and 2-qt rates were applied to additional plots in September 1979. The 1-qt rate was effective on thimbleberry and snowberry. The 2-qt rate controlled mountain maple and serviceberry. Three quarts per acre was required to control ninebark and produced 36 percent control on huckleberry. White pine and grand fir were not damaged. The 2- and 3-qt rates produced tip dieback on one-third of the Douglas-fir sprayed in early August. The September application produced no conifer injury.
KEYW Herbicides, Roundup.

415 AUTH Miller, D. L.
DATE 1981
TITL Should soil be firmed around seedling roots?
PUBL Forest Research Note RN-81-2. Lewiston, ID: Potlatch Corporation. 5 p.
ABST Containerized Douglas-fir and white pine were planted on five sites during late fall 1979 and early and late spring 1980. Half of

the seedlings planted had soil packed around the root plug. The rest were planted in dibble holes without packing. First-year results indicated that packing is not critical for late fall planting. Packing did produce a 0.7-inch (30 percent) height growth increase for early and late spring white pine plantings, and a 0.8-inch (35 percent) increase for late spring Douglas-fir plantings. Although survival was not significantly affected by root packing in this study (perhaps because of adequate soil moisture), packing is still recommended until data from drier years are available.
KEYW Planting procedure.

416 AUTH Miller, D. L., Breuer, D. W.
DATE 1984
TITL Effects of site preparation by burning and dozer scarification on seedling performance.
PUBL Forest Technical Paper TP-84-1. Lewiston, ID: Potlatch Corporation. 7 p.
ABST Containerized Douglas-fir and western white pine seedlings were planted on broadcast-burned, dozer-scarified, burned piles and untreated clearcut sites in northern Idaho. After three growing seasons, white pine seedlings were significantly taller on the untreated site. First-season Douglas-fir growth was better on the burned sites. After the third season, Douglas-fir seedlings on the scarified site were significantly shorter than on the other treatments. Survival of both species through the third year was not significantly affected by site preparation treatment. Competing vegetation cover was light on the untreated controls and may be responsible for the lack of significant advantage of site-prepared plots.
KEYW Site preparation, planting success.

417 AUTH Miller, D. L., Pope, W. W.
DATE 1982
TITL The effects of Garlon 3A and Garlon 4 on north Idaho conifers and shrubs.
PUBL Forest Technical Paper TP-82-3. Lewiston, ID: Potlatch Corporation. 11 p.
ABST The suspension of 2,4,5-T for forestry uses has produced the need for efficacy data for new and relatively untried herbicides. Toward this end, Garlon 3A and Garlon 4 herbicides were aerially applied to test plots in northern Idaho in September 1979. Garlon 4 at 3 lb ai/acre produced 94 percent control of snowbrush ceanothus three years following treatment. This rate produced 59 percent second-season mountain maple control. Third-season maple control was only 22 percent, however. Garlon 4, at 5 lb ai/acre, controlled huckleberry and sticky currant, but not thimbleberry; perhaps because of the late summer spray date. Garlon 3A was not effective for brush control. It produced 24 percent control on cherry, but produced little or no control on all other species. Garlon 4 application resulted in no conifer leader kill, but did moderately defoliate white pine (24 percent) and grand fir (27 percent) at the 5 lb ai/acre rate. Third-season height growth was normal. Garlon 3A produced no conifer damage at 3 lb ai/acre.
KEYW Herbicides, Garlon.

418 AUTH Miller, D. L., Schaefer, R. M.
DATE 1984
TITL The effects of container size on white pine and Douglas-fir survival and growth in north Idaho.
PUBL In: Proceedings, Joint Manufacturing, Western Forest Nursury Council/ Intermountain Nurseryman's Association. p. 1-5.
ABST This study was designed to determine the effect container size has on field survival and growth of western white pine. Between 1978 and 1982 field tests were installed in 13 plantations, and height growth and survival of styro-2, 4, and 8 seedlings were tracked for 2 to 5 years. Results indicate that styro-2 white pine survived as well as larger seedlings although height growth was slightly less. Greenhouse disease problems currently prevent growing operational quantities of styro-2 white pine, however. Styro-2 Douglas-fir performed as well as styro-4 seedlings on most sites. Styro-2 seedlings may be used on all but the driest Douglas-fir sites. In general, styro-8 seedlings were larger when planted and produced better height growth than styro-2 or 4 white pine and Douglas-fir seedlings. Increased survival and growth did not compensate for increased styro-8 production costs, however.
KEYW Containers, seedlings.

419 AUTH Miller, P. R.
DATE 1973
TITL Susceptibility to ozone of selected western conifers.
PUBL Abstracts of Papers, 2d International Congress of Plant Pathologists, Minneapolis, MN.
ABST The relative susceptibility to ozone of 12 western conifer species and two pine hybrids was investigated at Lake Arrowhead, in southern California. The injury scores representing order of decreasing susceptibility were: 15 down to 10—*Pinus monticola, P. jeffreyi* x *coulteri, Abies monticola, P. radiata* x *attenuata,* and *P. ponderosa*; 9.99

down to 5—*P. coulteri, Pseudotsuga menziesii, P. jeffreyi, P. ponderosa* (Rocky Mountain), *Abies concolor, Pseudotsuga macrocarpa,* and *P. attenuata*; 4.99 down to 1.5—*Libocedrus decurrens, P. lambertiana,* and *Sequoia gigantea*.
KEYW Ozone susceptibility.

420 AUTH Minore, D.
DATE 1979
TITL Comparative autecological characteristics of northwestern tree species—a literature review.
PUBL General Technical Report PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 72 p.
ABST This report is a compilation of autecological information previously scattered about in several hundred publications. It includes a comparison of the tolerance, traits, and attributes of native northwestern tree species. The species are ranked with respect to 69 environmental factors, phenotypic characteristics, and physical parameters.
KEYW Autecology, native plants.

421 AUTH Minore, D., Dubrasich, M. E.
DATE 1981
TITL Regeneration after clearcutting in subalpine stands near Windigo Pass, Oregon.
PUBL Journal of Forestry. 79: 619-621.
ABST Subalpine units of mountain hemlock near Windigo Pass, OR, did not regenerate immediately after being clearcut between 1959 and 1962. They were adequately stocked 9 to 12 years later, however, regardless of postharvest treatment. Natural regeneration was adequate. Major regenerating species were mountain hemlock, western white pine, lodgepole pine, Shasta red fir, Ponderosa pine, Pacific silver fir, and Douglas-fir.
KEYW Regeneration.

422 AUTH Mirov, N. T.
DATE 1946
TITL Viability of pine seed after prolonged cold storage.
PUBL Journal of Forestry. 44(3): 193-195.
ABST Reports on germination of seed of 21 species of pine kept in cold storage for periods ranging from 5 to 15 years. The results show that seeds of some pines will keep for a long time without losing their viability.
KEYW Pine seed, cold storage, viability, seed germination, stratification.

423 AUTH Mirov, N. T., Iloff, P. M., Jr.
DATE 1954
TITL Composition of gum turpentines of pines. XX. A report on *Pinus chihuahuana* from Durango, *P. apacheca* from Arizona, and *P. monticola* from northern Idaho.
PUBL Journal of American Pharmacology Association. 63: 378-381.
ABST Oleoresin from western white pine used in this investigation was obtained from Priest River Experimental Forest, ID, the area of optimal development of this species. The turpentine was obtained by heating oleoresin under reduced pressure so that at the end of distillation, the temperature reached 180 degrees and the pressure was 0.1 mm of mercury. Yield of turpentine was 20 percent. *Pinus monticola* from northern Idaho contained 2-3 percent n-heptane, 32 percent 1-and-dl-alpha-pinene, 45 percent 1-beta-pinene, 7 percent 1-limonene, 2 percent undecane, 2 percent bornyl acetate, 4-5 percent sesquiterpenes of which one is monocyclic and another bicyclic, and 7 percent pot residue and loss.
KEYW Oleoresin.

424 AUTH Moessner, K. E.
DATE 1963
TITL A test of aerial photo classifications in forest management-volume inventories.
PUBL Research Paper INT-3. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 16 p.
ABST A number of photo and map stratification schemes were studied using data from the St. Regis (Montana) test area in the western white pine type. Photo-volume classes offer the best means of stratification.
KEYW Aerial photo classification, volume inventory.

425 AUTH Moeur, M.
DATE 1981
TITL Crown width and foliage weight of Northern Rocky Mountain conifers.
PUBL Research Paper INT-283. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.
ABST Equations were derived for predicting crown width of trees from diameter, height, crown length, and basal area per acre, and for predicting foliage weight of trees from diameter, height, crown length, age, relative diameter, and number of trees per acre. Coefficients were estimated for 11 conifer species in northern Idaho and western Montana. Embedding these equations in the Prognosis Model for Stand Development will enhance the prediction of vegetation

characteristics needed for interfacing insect outbreaks, wildlife habitat, and watershed models.
KEYW Crown width prediction, Prognosis Model, stand development.

426 AUTH Molina, R., Trappe, J. M.
DATE 1982
TITL Patterns of ectomycorrhizal host specificity and potential among Pacific Northwest conifers and fungi.
PUBL Forest Science. 28(3): 423-458.
ABST Twenty-seven fungus species with diverse sporocarp-host associations were tested for ectomycorrhiza formation with seven Pacific Northwest conifers: *Pseudotsuga menziesii, Tsuga heterophylla, Larix occidentalis, Picea stichensis, Pinus contorta, P. ponderosa,* and *P. monticola*. The fungi varied widely in their ability to form mycorrhizae with the various conifers. The fungi with wide sporocarp-host associations showed no incompatibility with any of the hosts, and it is suggested that they may share a compatibility or recognition factor common to many ectomycorrhizal hosts. The specialized fungi with specific sporocarp-host associations often showed incompatibility with other nonassociated hosts. Disruption of the cortex by the invading fungus and lignification as indicated by intense safranin staining of cortical cells were the most common indicators of incompatibility. This host reaction suggests a type of phenolic defense mechanism as displayed in many plant-pathogen interactions.
KEYW Symbionts, mycorrhiza.

427 AUTH Molnar, A. C.
DATE 1955
TITL Development of pole blight in permanent sample plots.
PUBL Unpublished report. Victoria, BC: Canadian Department of Agriculture, Forest Biology Division, Forest Biology Laboratory. 20 p.
ABST Data collected from permanent sample plots are tabulated and discussed. Pole blight has continued to increase in all plots. Crown position had an influence on the rate trees became diseased, and intensification of symptoms and decline of trees was more severe with rise in crown position. Sanitation thinnings did not decrease pole blight.
KEYW Pole blight, *Dendroctonus, Dioryctria, Vespamima, Armillaria mellea*, pole blight crown class, pole blight thinning plots.

428 AUTH Molnar, A. C.
DATE 1956
TITL *Pullularia pullulans* associated with a flagging disease of western white pine.
PUBL Unpublished report. Victoria, BC: Canadian Department of Agriculture, Forest Biology Division, Forest Biology Laboratory. 20 p.
ABST A disease causing flagging of twigs and branchlets of immature western white pine is reported. The causal agent appears to be *Pullularia pullulans*.
KEYW *Pullularia pullulans, Pineus*.

429 AUTH Molnar, A. C., McMinn, R. G.
DATE 1958
TITL The current status of pole blight in British Columbia.
PUBL Canadian Department of Agriculture, Science Service, Bi-monthly Progress Report. 14(3): 3-4.
ABST In British Columbia, the pole blight disease of western white pine has been under continuous observation and investigation since it was first discovered in 1949. Early surveys and plot records indicated an alarmingly rapid intensification of the disease, and heavy losses from mortality were anticipated. While these early fears were justified by the rapid progress of the disease on permanent sample plots up to 1953, more recently there has been a marked decrease in disease intensification. An improvement in stand condition has, in fact, been recorded on both disease progress and thinning plots, and a similar trend has been observed in other pine stands. This trend appears to have been sufficiently sustained to warrant a reappraisal of the potentialities of pole blight.
KEYW Pole blight, British Columbia.

430 AUTH Molnar, A. C., McMinn, R. G.
DATE 1960
TITL The origin of basal scars in British Columbia interior white pine type.
PUBL Forestry Chronicle. 36: 50-60.
ABST Basal scarring, a conspicuous abnormality of western white pine and its associated species in the interior region of British Columbia, was found to be chiefly attributable to injury by bears, infections of *Armillaria mellea*, fire, mechanical wounding, and the pole blight disease. Diagnostic characteristics, which facilitated classification of scars, even those of advanced age, were found and described. The implications of the various types of scarring are considered.
KEYW Basal scars, bear damage, *Armillaria mellea*, fire damage, pole blight.

431 AUTH Morrell, F.
DATE 1924
TITL Forest economics in north Idaho.
PUBL Idaho Forester. 6: 6-8, 49.

ABST There are about 10 million acres of forest lands north of the Salmon River. Forty-six percent of this area bears merchantable timber. Thirty-three percent bears a stand of poles, young growth, and reproduction. The author further discusses the productive capabilities, value of the timber, and impact on the population of Idaho.
KEYW Forest economics.

432 AUTH Morrison, H.
DATE 1941
TITL Injury by sugar pine *Matsucoccus* scale resembles that of blister rust.
PUBL Journal of Forestry. 39: 488-489.
ABST *Matsucoccus paucicicatrices* damage to *Pinus lambertiana* resembles that of white pine blister rust (*C. ribicola*). Early stages of injury are sometimes so similar to blister rust cankers that microscopic examination is necessary for a positive diagnosis. In light of this, added difficulties can be expected in determining yearly blister rust advances throughout the range of commercial sugar pine.
KEYW *Matsucoccus paucicicatrices, Pinus lambertiana*, white pine blister rust, flags, cankers.

433 AUTH Moss, V. D.
DATE 1943
TITL Preliminary report on the use of germinated seed as a method of reforestation for western white pine.
PUBL Berkeley, CA: U.S. Department of Agriculture, Division of Plant Disease Control Series 115. 31 p. [Mimeo.]
ABST Direct seeding is reviewed in the light of four principal factors: (1) control of seed-eating rodents (mechanical protectors and poison baits), (2) germination of a sufficient number of seeds to provide a fully stocked stand of timber (fall sowing, spring sowing), (3) adequate control of seedling mortality (cutting insects, drought, insolation, fungi), and (4) reduction of cost below that of standard planting for establishment of comparable forest cover. Data are shown from field plots on light, soil moisture, and soil temperature in relation to germination, establishment, and survival of western white pine to justify a tentative conclusion that artificially germinated pine seed may be safely sown in the early spring sooner than it would germinate under natural conditions.
KEYW Direct seeding, rodents, seed germination, fall sowing, spring sowing, cutting insects, drought, insolation, fungi.

434 AUTH Mott, R. L., Amerson, H. V.
DATE 1981
TITL Tissue culture plantlets produced from *Pinus monticola* embryonic materials.
PUBL Forest Science. 27: 299-304.
ABST Methodology for tissue culture propagation of clones from western white pine, *Pinus monticola*, embryonic materials is presented, and the efficiency of clone production is discussed. Bud initiations from excised cotyledons yielded 17.6 buds per clone, whereas initiations from whole embryos yielded 7.4 buds per clone. Regardless of the initiation method, about 19 percent of the buds initiated eventually elongated to a height of 5 mm or more. Currently, 30 percent of these can be rooted.
KEYW Adventitious buds, conifer culture, clone production efficiency, propagule rooting.

435 AUTH Murison, W. F.
DATE 1959
TITL Ecological and physiological requirements of western white pine, grand fir and Engelmann spruce.
PUBL In: Ecology of the forests of the Pacific Northwest. Progress Report, 23 p. Appendix B, p. 6-11. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID.
ABST Qualitative data are presented for each of five species showing the severity and area of concentration of deficiency symptoms related to low levels of N, S, Mg, Ca, P, and K. Quantitative data have been collected also, some of which are presented here.
KEYW Ecological requirements, *Abies grandis, Picea engelmannii*.

436 AUTH Mutuura, A., Munroe, E., Ross, D. A.
DATE 1969
TITL American species of *Dioryctria* (Lepidoptera: Pyralidae).
PUBL Canadian Entomologist. 101: 1009-1023.
ABST *Dioryctria tumicolella* from pine blister rust, peridermium swellings on *P. contorta* in British Columbia, Alberta, and Washington, and *D. banksiella* from trunks of *P. banksiana* in Alberta, Northwest Territories, and eastward are described as new species and distinguished from the western *D. cambiicola* and the eastern *D. zimmermani*.
KEYW *Dioryctria monticolella, Dioryctria*, Lepidoptera.

437 AUTH Nemeth, L. J.
DATE 1967
TITL Determination of allowable working stresses for vertically laminated beams.
PUBL Forest Products Journal. 17: 23-30.
ABST Gives results of stress tests on western white pine vertically laminated beams of three laminations.

KEYW Working stress, laminated beams.

38 AUTH Nettleton, H. I.
DATE 1962
TITL Growth of white pine on logged-off areas.
PUBL University of Idaho Bulletin. 3(5): 1-2.
ABST Release of suppressed western white pines following logging is discussed in terms of diameter and height growth changes. Response in both growth catagories is positive. Logging of these released trees is presented as both profitable and feasible.
KEYW Growth release.

39 AUTH New Zealand Forest Service
DATE 1967
TITL *Dothistroma pini* project.
PUBL New Zealand Forest Service, Forest Research Institute, Annual Report. 67: 47-55.
ABST The indications given in last year's report are largely confirmed, except that young *Pinus muricata* now appears to be very highly susceptible, falling in the same catagory as *P. attenuata*. A few individual trees of *P. ayacahuite, P. patula, P. strobus, P. pseudostrobus,* and *P. michoacana* are mildly susceptible, while 50-75 percent of the trees of *P. lambertiana, P. monticola, P. taeda, P. contorta,* and *P. elliottii* show traces of the disease. Only *P. montezumae* shows no evidence of infection. Clones grafted from mature *P. radiata* trees onto young rootstock are as susceptible as normal seedlings.
KEYW *Dothistroma pini*, susceptibility, resistance, white pine species.

40 AUTH Nickle, W. R.
DATE 1960
TITL Nematodes associated with the rootlets of western white pine in northern Idaho.
PUBL Plant Disease Reporter. 44: 470-471.
ABST Several genera of plant-parasitic nematodes have been found in soil and root samples taken throughout the white pine type in northern Idaho. This investigation was carried out to provide information pertaining to a disease of western white pine known as pole blight. Female nematodes of the genus *Heterodera* have been found embedded in white pine rootlets taken from a diseased stand. These forms appeared destructive to the mycorrhizal rootlets. Observations and preliminary tests indicate that western white pine is a host of *Trichodorus elegans* Allen. This stubby-root nema has been found in all pole-blighted areas sampled and was not generally found in stands that did not exhibit pole blight symptoms. Other plant parasitic nematodes, belonging to the genera *Criconemoides, Criconema, Helicotylenchus,* and *Tylenchorhynchus*, have been recovered from soil samples taken from the rhizosphere of diseased white pine trees.
KEYW Pole blight, *Heterodera, Trichodorus, Criconemoides, Criconema, Helicotylenchus, Tylenchorhynchus,* nematodes.

441 AUTH Nickles, W. C., Rowe, J. W.
DATE 1962
TITL Chemistry of western white pine bark.
PUBL Forest Products Journal. 62: 374-376.
ABST Analyses of western white pine bark show that it contains up to 25 percent of extractives that can be removed by successive extraction with benzene, alcohol, and water, 30 percent of carbohydrate that was not extracted by neutral solvents, 39 percent of "lignin," and 1.2 percent of ash. The amounts of different sugars and other constituents in the whole bark as well as in the residues from extracting the whole bark with neutral solvents and hot 1-percent aqueous sodium hydroxide solution were determined in this study.
KEYW Bark chemicals.

442 AUTH Nord, F. F., Hata, K.
DATE 1969
TITL Fungal degradation of pine bark lignin.
PUBL In: Current aspects of biochemical energetics. New York: Academic Press. p. 315-329.
ABST The outer bark of western white pine was exposed to the enzymatic activity of white-rot fungi and the change in the amount of bark components, especially lignin, was studied in comparison with those components of wood. The degradation of the bark was very difficult even after preparing an extractive-free sample. *Collybia butyracea* decomposed lignin in bark as well as in wood. Bark phenolic acids could hardly be degraded by the fungi, whereas bark MW lignin was degraded as easily as wood MW lignin. The degradation compounds from the decayed bark and wood medium were studied by thin-layer chromatography. Vanillic acid was identified from the wood medium, and protocatechuic acid, extensively, from the bark medium, indicating that at the earlier stage of degradation of bark the fungus destroys mainly bark phenolic acids that are covering lignin and other components of bark.
KEYW Bark lignin, fungal degradation, white rot fungi, *Collybia butyracea*, bark phenolic acids.

443 AUTH Ollieu, M. M., Schenk, J. A.
DATE 1966

TITL The biology of *Eucosma rescissoriana* Heinrich in western white pine in Idaho (Lepidoptera: Olethreutidae).
PUBL Canadian Entomologist. 98: 268-274.
ABST *Eucosma rescissoriana* Heinrich is highly destructive to cones and seed of western white pine and is distributed throughout the geographic range of this host species in northern Idaho. One generation is passed per year with emergence in late May. Egg and larval stages are generally found in June and July; the pupal stage overwinters. Stand density and elevation were used as variables in ecological studies of population size. All stages of *E. rescissoriana* were correlated to phenological data in 1962.
KEYW Cone insects, seed insects, *Eucosma rescissoriana*.

444 AUTH Olson, D. S.
DATE 1923
TITL Forest planting in Montana and northern Idaho.
PUBL Applied Forestry Note 40. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST In the white pine type, 27,000 acres had been planted by 1923, with 90 percent having an established stand of 100 or more trees per acre. A conservative estimate of acreage needing reforestation was 75,000 acres (acres that had been burned over two or more times). Direct seeding was abandoned because of rodents and summer droughts.
KEYW Planting, reforestation, direct seeding.

445 AUTH Olson, D. S.
DATE 1930
TITL Growing trees for forest planting in Montana and Idaho.
PUBL Circular 120. Washington, DC: U.S. Department of Agriculture. 91 p.
ABST Discusses the selection and a development of a nursery site and thoroughly describes all nursery practices at the Savenac Nursery.
KEYW Nursery, seed storage, planting stock, seed germination, Savenac Nursery, nursery practices.

446 AUTH Olson, D. S.
DATE 1932
TITL Germinative capacity of seed produced from young trees.
PUBL Journal of Forestry. 30: 871.
ABST Casual observations show that *P. monticola* may bear cones as early as 10 years of age. Seed tests of 600 seeds each from seven lots showed that 10- to 17-year-old trees averaged 39 percent germination, 21- to 26-year-old trees averaged 55 percent germination. This compares with 54.5 percent for a large quantity of seed from trees 60 years old and over.
KEYW Seed germination, young trees, cone production, *Pinus ponderosa, Pinus contorta, Larix occidentalis, Thuja plicata.*

447 AUTH Olson, D. S.
DATE 1932
TITL Seed release from western white pine and ponderosa pine cones.
PUBL Journal of Forestry. 30: 748-749.
ABST A very meager experiment based on two cones of western white pine and ponderosa pine found that most of the seed was released in the spring. This was an unexpected result.
KEYW Seed release.

448 AUTH Olson, D. S.
DATE 1952
TITL Underground damage from logging in the western white pine type.
PUBL Journal of Forestry. 50: 460-462.
ABST "Logging shock" results in considerable loss of trees and arrested growth in residual stands of western white pine type. In the past, emphasis has been placed almost entirely upon logging damage above ground. Modern methods of logging are causing much damage underground—to roots of the residual trees. This type of damage may be very severe and may require changes in cutting practices for the western white pine type. The problem seems to be serious enough to warrant intensive investigation.
KEYW Logging damage, underground damage, pole blight, root damage, growth.

449 AUTH Olson, D. S.
DATE 1953
TITL Preliminary tests on relative inflammability of logging slash by species in western white pine type.
PUBL Research Note 5. Moscow, ID: University of Idaho, Forest, Wildlife, and Range Experiment Station. 6 p.
ABST Past concepts of slash inflammability by species are upset, especially by the unexpected fire behavior in western larch, western hemlock, and western redcedar slash. There undoubtedly is a short period when larch needles provide a "flashy" fuel for rapid flame spread. At other times, this species may be the least dangerous. Western hemlock may be more dangerous than commonly rated because of the high ratio of needles and fine twigs to branchwood. The same is true of Douglas-fir and Engelmann spruce. Inflammability in

spruce slash is reduced by early needle cast. Fires in the pine plots generated a great deal of heat.
KEYW Logging slash inflammability.

450 AUTH Olson, D. S.
DATE 1953
TITL Solids and voids in logging slash.
PUBL Research Note 8. Moscow, ID: University of Idaho, Forest, Wildlife, and Range Experiment Station. 4 p.
ABST Logging slash in its natural form is a loose, bulky mass. The high ratio of foliage to branchwood volume presents two important considerations: (1) The large volume of "kindling fuels" makes the slash highly inflammable. (2) The most inflammable portion of the slash may be expected to separate from the coarser material and decompose in a relatively short time.
KEYW Logging slash, branchwood solids, needle solids, *Tsuga heterophylla, Thuja plicata, Picea engelmannii, Pseudotsuga menziesii.*

451 AUTH Olson, D. S., Fahnestock, G. R.
DATE 1955
TITL Logging slash: a cooperative study of the problem in Inland Empire forests.
PUBL Idaho Forester. 1: 52.
ABST Describes the biological and legal problems with logging slash from a practical and a research point of view.
KEYW Logging slash, slash disposal, slash inflammability.

452 AUTH On, D.
DATE 1952
TITL 2,3,5-triphenyl tetrazolium chloride as a viability indicator of certain coniferous seeds.
PUBL Journal of Forestry. 50: 868.
ABST 2,3,5-triphenyl tetrazolium chloride was tested for use as a seed viability indicator for western white pine, pinyon pine, ponderosa pine, and Douglas-fir. Results correlated closely with results of direct germination tests.
KEYW Seed viability, tetrazolium, viability indicator.

453 AUTH Otter, F. L.
DATE 1933
TITL Idaho's record trees.
PUBL Idaho Forester. 15: 37-39.
ABST The following record western white pines are listed: cut - Marble Creek, 92-inch stump, 480 years; standing - Little North Fork of the Clearwater River, 84 inches d.b.h.; cut - Kaniksu National Forest (cut 1922, 15 merchantable logs; no other measurements available).
KEYW Record trees.

454 AUTH Owens, J. N., Molder, M.
DATE 1977
TITL Development of long-shoot terminal buds of western white pine (*Pinus monticola*).
PUBL Canadian Journal of Botany. 55: 1308-1321.
ABST Long-shoot terminal bud (LSTB) development in western white pine was studied throughout the annual growth cycle to determine the phenology of LSTB development and the time of cone-bud differentiation. Development of LSTB began in early April and cataphylls were initiated from mid-August until early November. Cataphyll initiation was slow during May and June when shoots were elongating and then rapid just after shoot elongation was completed. Proximal cataphylls were sterile, whereas more distal cataphylls began to initiate axillary buds by late June or early July. Axillary buds were initiated first in the proximal portions of the LSTB and then acropetally in rapid succession. The last cataphylls to be initiated in the fall remained as sterile bud scales enclosing the LSTB apex. Axillary buds initiated sterile cataphylls which functioned as bud scales. Attempts to induce or enhance seed-cone production in *P. monticola* would probably be most successful in the spring when seed-cone buds differentiate. LSTB-bearing seed cones were larger, had broader apices, and produced more cataphylls during the growing season than did LSTB-bearing pollen cones.
KEYW Long-shoot terminal buds, phenology terminal buds, axillary buds, seed cones, pollen cones, cataphyll initiation, cone-bud differentiation.

455 AUTH Packer, P. E.
DATE 1962
TITL Elevation, aspect, and cover effects on maximum snowpack water content in a western white pine forest.
PUBL Forest Science. 8: 225-235.
ABST Maximum snowpack water content in a small white pine-forested watershed in northern Idaho during four winters was related to elevation, aspect, and density of forest canopy. The largest increases in snow water content occurred with diameter and basal area reductions in the densest forest stands and became smaller with comparable diameter and basal area reductions in more open stands.
KEYW Water content, snowpack.

456 AUTH Packer, P. E.
DATE 1971
TITL Terrain and cover effects on snowmelt in a western white pine forest.

PUBL Forest Science. 17(1): 125-134.

ABST Whether increases in snowpack water that result from cutting timber in western white pine forests of the Northern Rocky Mountains can create flood-producing conditions depends, in part, upon the melting behavior of the snowpack under various terrain and forest conditions. Reported are results of a 4-year study which show that snowmelt (ablation) rates are influenced significantly by differences in terrain and forest cover conditions.

KEYW Snowmelt, stand density, air temperature, radiant energy.

457 AUTH Parker, A. K.

DATE 1951

TITL Pole blight recorded on the British Columbia coast.

PUBL Forest Pathology Note 4. Victoria, BC: Dominion Laboratory of Forest Pathology. (Mimeo.)

ABST Describes the presence of pole blight on the coast. A fungus, tentatively identified as a species of *Scopularia*, was isolated from one of the affected trees.

KEYW Pole blight, *Scopularia*.

458 AUTH Parker, A. K.

DATE 1953

TITL Pole blight of western white pine.

PUBL Canadian Department of Agriculture, Science Service Bi-monthly Progress Report. 9(1): 4.

ABST Of the nine fungi most frequently isolated in 1949 and 1950 from white pines affected by the pole blight, only a species of *Leptographium* was found capable of producing lesions similar to those associated with the disorder. Inoculation experiments in the interior and coastal regions indicated an association of the *Leptographium* sp. with pole blight. In the light of data obtained through current studies and from previous analyses of affected trees, however, there is considerable doubt that this fungus is the sole cause of the disorder.

KEYW Pole blight, *Leptographium*.

459 AUTH Parker, A. K.

DATE 1957

TITL The nature of the association of *Europhium trinacriforme* with pole blight lesions.

PUBL Canadian Journal of Botany. 35: 845-856.

ABST *Europhium trinacriforme* was the only organism isolated more than twice from pole blight lesions and found to be pathogenic to white pine. However, examinations of the number and size of lesions on pole-blighted trees and the results of inoculations, isolations, and histological studies indicated that *E. trinacriforme* most likely gains entrance to lesions that are already formed from other causes and extends them.

KEYW *Europhium trinacriforme*, pole blight lesions, inoculation, radial increment.

460 AUTH Parker, A. K.

DATE 1958

TITL Studies on *Europhium trinacriformis* spec. nov. the perfect stage of a species of *Leptographium* isolated from lesions on western white pine affected with pole blight.

PUBL Forestry Chronicle. 34: 328.

ABST The perfect stage of a species of *Leptographium* isolated from lesions on western white pine affected with pole blight has been described as *Europhium trinacriformis* and a method has been outlined for obtaining *perithecia* in culture. Studies on the sexuality of the fungus have revealed it to be heterothallic with two compatability types. Cross-fertilization experiments revealed the presence of isolates which acted as either males, females, or hermaphrodites. *E. trinacriformis* was isolated from 11 percent of the lesions on western white pine affected with pole blight in the interior region of British Columbia and from 84 percent of the lesions on affected trees in the coast region. The fungus was the only pathogenic organism isolated more than twice from lesions, and it was shown to be capable of producing lesions similar in several respects to pole blight lesions. However, further data from isolation, inoculation, histological, and radial growth studies have shown that pole blight lesions were not caused directly by *E. trinacriformis*. It is most likely that the fungus gained entrance to lesions already formed and occasionally extended them.

KEYW *Europhium trinacriformis, Leptographium*, pole blight.

461 AUTH Parker, A. K., Collis, D. G.

DATE 1966

TITL *Dothistroma* needle blight of pines in British Columbia.

PUBL Forestry Chronicle. 42: 160-161.

ABST *Dothistroma* needle blight is reported to be widespread throughout British Columbia on three native pines, and present on six species of exotic pines grown on Vancouver Island. A description of the disease is given.

KEYW *Dothistroma pini*, needle blight, British Columbia, *Actinothyrium marginatum*.

462 AUTH Parker, A. K., Mulnar, A. C.

DATE 1952

TITL Pole blight of western white pine.

PUBL Canadian Department of Agriculture, Science Service, Bi-monthly Progress Report. 7(6): 4.
ABST The final series of permanent sample plots arising from the pole blight survey have been established in the Nelson Forest District of British Columbia. This work, initiated in 1950, has the following main objectives: (1) to study the progress of pole blight symptoms within individual trees, (2) to determine the nature of spread of the disease, (3) to determine the feasibility of control through sanitation thinning. The first authentic record of pole blight in living white pine in the coastal region of western North America has been made near Duncan, BC, and analyses have indicated its presence there for at least 8 years. Additional scouting has subsequently confirmed its presence near Bowser and Qualicum Bay on Vancouver Island and near Hope on the adjacent mainland. Cultural studies are being undertaken on a species of *Scopularia*, a fungus commonly associated with the disease and known to be capable of producing lesions similar to those found on pole-blighted trees.
KEYW Pole blight, pole blight survey, *Scopularia*.

3 AUTH Parker, A. K., Waldie, R. A., Foster, R. E.
DATE 1950
TITL Pole blight, a previously unreported disease of western white pine in British Columbia.
PUBL Forest Pathology Note 3. Victoria, BC: Dominion Laboratory of Forest Pathology. (Mimeo.)
ABST The first reported appearance of pole blight in Canada is described and mapped.
KEYW Pole blight.

4 AUTH Parker, J.
DATE 1951
TITL Moisture retention in leaves of conifers of the Northern Rocky Mountains.
PUBL Botanical Gazette. 113: 210-216.
ABST Leaves of ponderosa pine retained more moisture when attached to cut branches than did those of Douglas-fir, western white pine, arborvitae, grand fir, or Engelmann spruce. Leaves of Douglas-fir and ponderosa pine retained a higher moisture content on the average when the leaves were removed from the branches and allowed to dry in the laboratory. Cut leaves of arborvitae and white pine showed no significant differences in moisture retained, but cut leaves of both species retained more moisture than did leaves of grand fir or spruce. The tetrazolium test did not indicate any results to substantiate the claim that the more drought-resistant coniferous species are better able to recover from a low content of leaf moisture than are those less drought-resistant. Leaf shrinkage was closely associated with water loss.
KEYW Moisture retention, leaves, tetrazolium test, drought.

465 AUTH Parker, J.
DATE 1952
TITL Environment and forest distribution of the Palouse Range in northern Idaho.
PUBL Ecology. 33: 451-461.
ABST In the Palouse Range of northern Idaho, the tree species show transitions from one habitat to another as one progresses along a compass line over varying topography.
KEYW Environment, forest distribution.

466 AUTH Paul, B. H.
DATE 1962
TITL Properties and uses of western pines.
PUBL Hitchcock's Wood Working Digest. 1962 January: 43-46.
ABST Western white pine is most abundant in northern Idaho. It occurs also in western Montana, Washington, and Oregon. Western white pine, known also as Idaho white pine, has physical and mechanical characteristics similar to eastern white pine. It is difficult to tell the two species apart except on the basis of origin. The lower grades of lumber are used for boxes, crates, and light construction. The better grades are shipped to eastern markets and utilized for the same purposes as eastern white pine. A considerable portion (20 percent in 1948) of the lumber cut is used for the manufacture of matches. It is also used for doors, frames, sashes, siding, and exterior and interior trim. Other uses are numerous; in fact it has been said that western white pine is suitable for use in nearly every part of a house, because of the ease with which it can be cut and shaped with tools, its ability to stay in place, its ability to take and hold paint and enamel, and its nailing properties.
KEYW Uses.

467 AUTH Pfister, R. D.
DATE 1969
TITL Effect of roads on growth of western white pine plantations in northern Idaho.
PUBL Research Paper INT-65. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST The potential loss of timber-producing land from roads is minor and can be reduced if road widths are kept to the minimum actually needed. Roads need to be less than 14 ft wide and trees must occupy the side up to the toe of the fill and near the top of the cut.

KEYW Roads versus timber production.

468 AUTH Pfister, R. D.
DATE 1974
TITL Habitat types and regeneration.
PUBL Permanent Association Committee Proceedings. Portland, OR: Western Forest and Conservation Association. p. 120-125.
ABST Discusses the habitat type method of ecological classification and its applications in regeneration planning, especially (1) choice of silvicultural systems, (2) choice of species, (3) site preparation techniques, (4) regeneration probabilities, (5) choice of regeneration methods, and (6) seed collection practices. Several examples are presented to illustrate this habitat type-regeneration planning relationship.
KEYW Habitat type, ecological classification, regeneration planning, silvicultural treatments, succession, site preparation, seed collection, environmental stratification, management guidelines.

469 AUTH Pfister, R. D., Kovalchik, B. L., Arno, S. F., Presby, R. C.
DATE 1977
TITL Forest habitat types of Montana.
PUBL General Technical Report INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 173 p.
ABST A total of nine climax series, 64 habitat types, and 37 phases of habitat types are defined. Potential productivity for timber, climatic characteristics, and surface soil characteristics are described for each type.
KEYW Habitat types, Montana habitat types.

470 AUTH Phelps, W. R., Leaphart, C. D.
DATE 1968
TITL A comparison of the translocation and persistence of cycloheximide (acti-dione) in eastern and western white pine.
PUBL Forest Science. 14: 275-276.
ABST After basal stem application, cycloheximide was absorbed and moved systemically throughout pole-size eastern and western white pine. It was translocated both upward and downward in the tree bole. The antibiotic was absorbed faster, and moved in greater quantities but at a slower rate, in eastern than in western white pine.
KEYW Cycloheximide, actidione, translocation.

471 AUTH Pillow, M. Y.
DATE 1953
TITL How growth of white pine affects its properties for matches.
PUBL FPL-1950. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 7 p.
ABST Research findings on growth and intrinsic wood characteristics can improve industrial inspection procedures by providing means of eliminating wood that is inherently weak due to the conditions under which it was grown. Variations in density and fiber structure can be discerned, and means of grading that exclude unsuitable forms are available and practical. Characteristics of value for grading purposes include annual ring width and variations in the form of compression wood.
KEYW Matches, density wood, fiber structure.

472 AUTH Pissot, H. J.
DATE 1953
TITL Forest resources of north Idaho.
PUBL Station Paper 35. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 26 p.
ABST Lists western white pine as the principal sawtimber tree, comprising 22 percent of board foot volume and 18 percent of cubic foot volume. White pine is also listed as being the principal species cut in the decade 1941-50, with 38 percent of the sawlog production being western white pine. Includes the following data for all principal species: estimated differences in area statistics by major land and stand-size class, area of commercial forest land by major forest types, net volume of live sawtimber and growing stock on commercial forest land by species, by diameter class groups, annual sawlog production, annual lumber production, annual pulpwood production, annual pole production, and forest type classes.
KEYW Species comparisons, forest types.

473 AUTH Pitman, G. B.
DATE 1971
TITL Trans-verbenol and alpha-pinene: their utility in manipulation of the mountain pine beetle.
PUBL Journal of Economic Entomology. 64(2): 426-430.
ABST As behavior-regulating chemicals, trans-verbenol and alpha-pinene were effective in manipulating the host selection patterns of *Dendroctonus ponderosae*. When 725 mature white pines, distributed over eight 40-acre plots in northern Idaho, were baited with the two materials, 133 or 18 percent were attacked heavily and subsequently killed. Prior to baiting, all trees were

sprayed to a height of about 20 ft with a 2.3 percent solution of lindane. The mortality of sprayed trees suggested that lindane was not effective under the conditions of this study. Only 21 of the estimated 7,200 unbaited mature pines within the boundaries of the study plots were mass attacked, and 11 of these trees were within 10 to 15 ft of baited mass-attacked trees. Paperboard cylinders covered with a tacky substance and baited with trans-verbenol and alpha-pinene appeared effective as a means of deadtrapping *D. ponderosae.*

KEYW *Dendroctonus ponderosae,* trans-verbenol, alpha-pinene, myrcene, limonene, manipulating, lindane, deadtrapping.

474 AUTH Plank, G. H., Gerhold, H. D.
DATE 1965
TITL Evaluating host resistance to the white-pine weevil, *Pissodes strobi,* (Coleoptera: Curculionidae) using feeding preference tests.
PUBL Annals of the Entomological Society of America. 58: 527-532.
ABST Results of experiments in which white-pine weevils, *Pissodes strobi,* were caged on cut leaders show that weevils are capable of distinguishing and expressing feeding preferences among three of their host species—eastern white pine, jack pine, and red pine—very similar to patterns observed in the field. There was no difference in amount of feeding on eastern white pine or western white pine, or between two classes based on past weeviling, despite a large difference in susceptibility. In none of the four species was amount of feeding correlated with any of the morphological features which were measured at 10 inches from the base of the terminal bud.
KEYW Host resistance, white pine weevil, *Pissodes strobi,* feeding preference.

475 AUTH Plank, M. E., Snellgrove, T. A.
DATE 1973
TITL Lumber yield from western white pine in northern Idaho.
PUBL Research Paper PNW-153. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 30 p.
ABST A sample of 300 trees was selected to represent the full range in size and quality of commercial sawtimber available in northern Idaho. A net log scale of 167,900 bd ft (Scribner) was sawed from 1,431 logs in a typical white pine mill, producing 212,703 bd ft of lumber. Lumber yields for each lumber grade are presented by log grade and diameter class. The study showed a recovery of 17 percent molding and selects; 5 percent No. 3 clear, No. 1 and 2 shop; and 78 percent common.
KEYW Log yield, lumber, forest industries.

476 AUTH Porter, A. W.
DATE 1964
TITL On the mechanics of fracture in wood.
PUBL Forest Products Journal. 14: 325-331.
ABST An elastic fracture theory based upon an energy balance has been successfully applied to the opening mode fracture of western white pine wood in the 1t and 1r planes. This approach led to the establishment of material parameter, termed the "strain-energy release rate" or GIC which was independent of changes in specimen geometry and crack length. Knowledge of GIC permits a prediction of combinations of stress and crack length which will result in rapid crack propagation and lead to final failure. GIC also provides a convenient basis for relating the fracture resistance of various woods, and wood to other materials. Through appropriate environmental testing, the total fracture energy was partitioned into two components. The first of these is the energy associated with wood acting purely as an elastic body; the second includes the energy to overcome vescoelastic effects.
KEYW Wood fracture, wood fracture resistance.

477 AUTH Potlatch Corporation
DATE 1952
TITL Pole blight: new threat to white pine.
PUBL The Family Tree. Lewiston, ID: Potlatch Corporation; 16: 3.
ABST Describes the discovery symptoms and danger of pole blight to western white pine in the Inland Empire.
KEYW Pole blight.

478 AUTH Powell, J. M.
DATE 1966
TITL Distribution and outbreaks of *Dendroctonus ponderosae* Hopk. in forests of western Canada.
PUBL Report A-X-2. Calgary, AB: Canadian Department of Environmental Information, Forest Research Laboratory. 19 p.
ABST Gives a general description of distribution and outbreaks of *D. ponderosae* in western Canada, including various outbreaks in *P. monticola.*
KEYW *Dendroctonus ponderosae,* British Columbia, distribution, outbreaks, *Pinus contorta, Pinus ponderosa, Picea engelmannii.*

479 AUTH Preston, J. F.
DATE 1924
TITL Forestry practice and possibilities in north Idaho.
PUBL The Timberman. 25: 49-50, 156-160.
ABST Describes silvicultural conditions, treatments, growth of trees, future prices.
KEYW Forest practices, forest management, silviculture.

480 AUTH Pryor, L. D.
DATE 1940
TITL The effect of fire on exotic conifers.
PUBL Australian Forester. 5: 37-38.
ABST Several species of exotic conifers, including western white pine, are ranked according to fire resistance at age 8 years. The importance of age, defoliation, and bark thickness as they relate to susceptibility to fire are discussed. The recurring ideas of interposing belts of resistant species at known danger points, and of using periodic control burns to prevent litter buildup are mentioned as possible management tools.
KEYW Exotic conifers, plantation, fire resistance, defoliation, cambium, epicormic shoots.

481 AUTH Raff, R. A. Y., Herrick, I. W., Adams, M. F.
DATE 1966
TITL Flame-retardant wood.
PUBL Forest Products Journal. 16: 43-47.
ABST The high energy irradiation of wood (western white pine) impregnated with unsaturated organophosphorus compounds is considered to be one application where the in situ radiation polymerization method can achieve an effect not otherwise obtainable. With even distribution of a flameproofing resin inside the wood, fire retardancy and leach resistance should result. Several commercially available organophosphorus monomers, some also containing halogen, were evaluated in this application. Only one of seven unsaturated phosphorus compounds was found to polymerize in a CO-60 source to a sizable extent, while all but one could be made to polymerize to a soft gel after 5 percent of a crosslinking monomer had been added. Western white pine, after impregnation in vacuo with any of these polymerizeable mixtures, followed by exposure to the gamma source, showed flameproofing properties in the crib test. The char remaining after combustion represented up to 58 percent of the impregnated wood samples. Photomicrographs of the char showed that the original wood structure was well preserved. After exposure in water for 14 days, the dried specimens still showed the same flame resistance as before leaching.
KEYW Flame-retardant, radiation polymerization, organophosphorus monomers.

482 AUTH Ramskill, J. H.
DATE 1934
TITL Thinning in the western white pine type.
PUBL Forestry Kaimin. Missoula, MT: University of Montana. p. 15-21.
ABST Some problems of thinning in the western white pine type of northern Idaho are discussed. Aside from possible increment increases, the pronounced improvement in stand quality resulting from a more desirable species mix should yield an increased financial return at maturity over unthinned stands. The extent to which this increase in value will cover the costs of thinning cannot be accurately discerned until final harvest. This article discusses thinning in terms of species desirability, basal area, trees per acre, cubic foot volume, spacing, crown classes, and other related factors.
KEYW Permanent plots, yield tables, thinning.

483 AUTH Rapraeger, E. F.
DATE 1936
TITL Effect of repeated ground fires upon stumpage returns in western white pine.
PUBL Journal of Forestry. 34: 715-718.
ABST The article describes three types of losses from ground fire: (1) understocking and reduced yield, (2) decay traceable to fire, and (3) roughness in trees. The author concludes that complete protection from fire is essential to growing quality western white pine.
KEYW Ground fire, stumpage, understocking, decay, roughness.

484 AUTH Rapraeger, E. F.
DATE 1936
TITL Relation of tree size in western white pine to log-making costs.
PUBL Applied Forestry Note 74. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Contains a graph comparing tree diameter to log-making costs (time expressed in man-minutes). The curves are based on time studies made near Orofino, ID, in a stand of western white pine timber 141 years of age.
KEYW Log cost, tree size.

485 AUTH Rapraeger, E. F.
DATE 1936
TITL What percent of tree volume is in each log of a western white pine tree?
PUBL Applied Forestry Note 75. Missoula, MT: U.S. Department of Agriculture, Forest

Service, Northern Rocky Mountain Forest and Range Experiment Station. 2 p.
ABST Gives tables showing percentage of gross volume contained in the butt log, second log, and other logs, including top log for western white pine trees approximately 140 years of age.
KEYW Log production, merchantable volume.

86 AUTH Rapraeger, E. F.
DATE 1938
TITL Results and application of a logging and milling study in the western white pine type of northern Idaho.
PUBL University of Idaho Bulletin. 33(16): 55.
ABST Data produced by a logging and milling study at the White Pine Lumber Company at Orofino, ID, and Clearwater National Forest are described and discussed. The effects of clearcutting and partial cutting are discussed. Data from time studies of various logging and milling elements are tabulated.
KEYW Cone crop tree diameter, crop tree dominance, milling, match plank, logging study, group cutting, partial cutting, clearcuts.

87 AUTH Rapraeger, E. F.
DATE 1939
TITL Development of branches and knots in western white pine.
PUBL Journal of Forestry. 37: 239-245.
ABST Two western white pines on Deception Creek Experimental Forest were studied to determine the development of branches and knots. It is suggested that increased stand density and pruning may decrease knotting.
KEYW Knots, stand density, branch size, branch longevity, knot length, pruning.

88 AUTH Rapraeger, E. F.
DATE 1939
TITL Log prices in the Northern Rocky Mountain Region.
PUBL Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The following statistics are given for western white pine from all Districts: quantity, 52,636 thousand bd ft log scale; average price per thousand bd ft, $18.49.
KEYW Log prices.

89 AUTH Rapraeger, E. F.
DATE 1939
TITL Matches from Idaho's white pine.
PUBL American Forester. 39(3): 1-3.
ABST Taking into account supply, price, and technical qualities, no wood in the United States is better suited for match manufacture than Idaho white pine. All important match companies draw their supply of match blocks from Idaho.
KEYW Products, matches.

490 AUTH Rapraeger, E. F.
DATE 1939
TITL Range of log prices, 1938 Northern Rocky Mountain Region.
PUBL The Timberman. 40(7): 28.
ABST For calendar year 1938, the following average log prices are given for western white pine: northeastern Washington - $16.11; St. Maries, Coeur d'Alene, Spokane - $19.00; Sandpoint - $17.12; Clearwater - $14.15; western Montana - $17.12; for an average of $18.49.
KEYW Log prices.

491 AUTH Rapraeger, E. F.
DATE 1939
TITL Results of a sawmill study of timber on ME plot 150 (Bearpaw Creek).
PUBL Unpublished report. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 33 p. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID.
ABST Results of a logging study on Bearpaw Creek, Kaniksu National Forest. Selling price of white pine and match plank, diameter growth data, and lumber yield are tabulated.
KEYW Tree growth, overrun, logging study, lumber yield crown class.

492 AUTH Rapraeger, E. F.
DATE 1939
TITL Tag ends of the logging and milling study at the White Pine Lumber Company operation at Orofino, Idaho.
PUBL Unpublished report. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 35 p. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID.
ABST Data produced by a logging and milling study at the White Pine Lumber Company at Orofino, ID, are tabulated and discussed. Production of match plank, effects of limb size, defect on match plank yields.
KEYW Milling, match plank, oversize sawing, overrun, sawing time.

493 AUTH Rapraeger, E. F.
DATE 1940

TITL Possibilities of partial cutting in young western white pine.
PUBL Paper 2. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 19 p.
ABST This paper deals with the technique of light cuts in young stands of western white pine. The technique involves at least three cuts: (1) A heavy thinning which takes about one-third of the volume in marketable trees 13.6 inches d.b.h. and larger. (2) A second cut when growth acceleration due to the initial cut begins to decline, probably from 10 to 20 years hence, taking about one-half of the remaining merchantable volume and leaving a shelterwood canopy. (3) A final cut to take the remainder of the stand after progeny have become well established, and to give release to regeneration. Advantages are listed as: release, accessibility, frequent cuttings, preservation of natural conditions, flexibility, early income, and better utilization.
KEYW Thinning, partial cutting.

494 AUTH Rehfeldt, G. E.
DATE 1979
TITL Ecotypic differentiation in populations of *Pinus monticola* in north Idaho—myth or reality?
PUBL American Naturalist. 114: 627-636.
ABST Full-sib families representing 12 populations of *Pinus monticola* were compared to assess local differentiation of populations in northern Idaho. Populations represented north and south aspects at three elevations (950, 1,175, and 1,400 m) in each of two drainages. Tests of 6-year-old seedlings growing in two contrasting environments revealed (1) little or no differentiation among populations, (2) genetic variation among families within populations, and (3) large environmental effects on growth and development. These results and other recent data suggest that adaptation of *P. monticola* to variable environments is governed more by phenotypic plasticity than by selective differentiation.
KEYW Ecotypic variation, phenotypic plasticity, provenance test

495 AUTH Rehfeldt, G. E., Hoff, R. J.
DATE 1977
TITL Proper seed source—a key to planting success.
PUBL In: Baumgartner, D. M.; Boyd, R. J., eds. Tree planting in the Inland Northwest. Pullman, WA: Washington State University Cooperative Extension Service. p. 43-48.
ABST The need for planting seedlings that are adapted to the site is discussed. Western white pine, Douglas-fir, and ponderosa pine are given as examples.
KEYW Seed source, seed transfer, provenance tests.

496 AUTH Rehfeldt, G. E., Hoff, R. J., Steinhoff, R. J.
DATE 1984
TITL Geographic patterns of genetic variation in *Pinus monticola*.
PUBL Botanical Gazette. 145(2): 229-239.
ABST Genetic differentiation of 59 populations representing the geographic distribution of *Pinus monticola* was studied in field, greenhouse, and laboratory tests. Geographic variation was described by regression models, which accounted for as much as 85 percent of the variance among populations. Populations from the north (Rocky Mountains, northern Cascades, and northern coastal areas) are generally of high growth potential and low cold hardiness. Southern populations (Sierra Nevada) exhibit low growth potential and high hardiness. Populations from the central and southern Cascades are arranged along relatively steep latitudinal clines that connect northern and southern groups. Although differentiation within the transitional region was readily detected, patterns of variation within northern and southern regions were either weak or nonexistent. Nowhere was genetic variation related to the elevation of the seed source.
KEYW Provenance test.

497 AUTH Rehfeldt, G. E., Stage, A. R., Bingham, R. T.
DATE 1971
TITL Strobili development in western white pine: periodicity, prediction, and association with weather.
PUBL Forest Science. 17: 454-461.
ABST Variation in yearly counts of female strobili during various stages of development was studied from 18-year records of four trees in northern Idaho. Spectral analyses indicated that periodicity in production of strobili by individual trees followed major cycles of 4 years; cycles of 3 years were of secondary importance. Cospectral analyses indicated that cycles of the four trees were in phase. Autoregression was used to develop models for predicting strobili production. Regressions involving lags of 4 years in the dependent variable accounted for 47 and 41 percent of the variation in counts of immature and mature strobili, respectively. Association of strobili production with daily moisture stress indicated: (1) water deficits during early summer of the year in which strobili matured were directly related to abortion of strobili; (2) moisture stresses during early summer of the first and second

years preceding emergence of strobili from the bud scales were associated with high strobili counts; and (3) water deficits during late summer in the year preceding strobili emergence were detrimental to strobili development.
KEYW Cone production, cone prediction, moisture stress.

498 AUTH Rehfeldt, G. E., Steinhoff, R. J.
DATE 1970
TITL Height growth in western white pine progenies.
PUBL Research Note INT-123. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Heights of 31 progenies of western white pines from four geographic localities and four crosses between localities were assessed on 14-year-old trees at two sites. Differences in height among individual progenies were detected but could not be related to localities or crosses between localities. Although differential effects of sites on tree height became apparent after age 9, differences among progenies were similar on both sites.
KEYW Height growth.

499 AUTH Rettig, E. C.
DATE 1942
TITL Cutting practices.
PUBL Journal of Forestry. 70: 366-367.
ABST Reviews cutting practices of Potlatch Forests, Inc., in Clearwater County, ID. Shelterwood cutting was the principal method used in young stands; seed tree method was used in mature stands.
KEYW Cutting practices, shelterwood cut, seed tree cut, slash disposal.

500 AUTH Righter, F. I.
DATE 1945
TITL *Pinus*: the relationship of seed size and seedling size to inherent vigor.
PUBL Journal of Forestry. 43: 131-137.
ABST In several experiments the author has endeavored to isolate and evaluate some of the factors ordinarily associated with vigor in pines. He concludes that seed size and seedling size are controlled more by environment than by heredity and cannot therefore be used as indicators of inherent vigor.
KEYW Seed size, seedling size, inherent vigor, *Pinus monticola* x *P. strobus*, seed weight.

501 AUTH Righter, F. I., Duffield, J. W.
DATE 1951
TITL Interspecies hybrids of pines.
PUBL Heredity. 42: 75-80.
ABST This article lists all pine hybrids which resulted in successful pollination at the Institute of Forest Genetics. *P. monticola* seed parents crossed with the following pollen parents were successful: *P. ayacahuite, P. peuce,* (*P. peuce* x *P. strobus*).
KEYW Hybrids, *Pinus monticola* x *P. griffithii, Pinus monticola* x *P. ayacahuite, Pinus monticola* x *P. peuce, Pinus monticola* x (*P. peuce* x *P. strobus*).

502 AUTH Rigkey, R. G., Hergert, H. L.
DATE 1974
TITL Reactions in pine heartwood during acid bisulfite pulping.
PUBL Tappi. 57(7): 114-117.
ABST Heartwood of a variety of pine species was experimentally pulped by the acid bisulfite process. Results varied from complete pulpability to no "pulping" whatsoever. Qualitative analyses for pinosylvin and related stilbenes, pulping inhibitors, showed them to be present in all species examined. Quantitative analyses indicated wide variation in the amounts of these compounds. A mechanism for the pulping inhibition is proposed.
KEYW Heartwood, acid bisulfite process, pulpability, pulping inhibitors.

503 AUTH Roberts, V. K.
DATE 1966
TITL A bibliography of publications by the Intermountain Forest and Range Experiment Station on the genetics and breeding of forest trees, 1921-1965.
PUBL Research Note INT-48. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.
ABST Lists all genetics publications of the Intermountain Station between 1921 and 1965. Many of these publications deal with western white pine, especially its resistance to blister rust.
KEYW Bibliography, genetics, breeding.

504 AUTH Robinson-Jeffrey, R. C., Davidson, R. W.
DATE 1968
TITL Three new Europhium species with *Verticicladiella* imperfect states on blue-stained pine.
PUBL Canadian Journal of Botany. 46: 1523-1527.
ABST Three new species in the genus *Europhium* (*E. clavigerum, E. aureum,* and *E. robustum*) with *Verticicladiella* imperfect states are described and figured. *Cleistothecia* are found on bark, sapwood, and in old beetle galleries of beetle-infested, blue-stained pines, including lodgepole, ponderosa, limber, and western white. *Europhium clavigerum* was found on all hosts, *E. aureum* on lodgepole,

and *E. robustum* on differences between the imperfect states. A key is provided to separate the *Verticicladiella* states of the three new species of *Europhium* and the *Leptographium* state of *E. trinacriforme*.
KEYW *Europhium claviaerum, Europhium aureum, Europhium rubustum, Verticicladiella, Leptographium, Europhium trinacriforme,* blue stain.

505 AUTH Rockwell, F. I.
DATE 1913
TITL Basis of classification into forest types and its application to District 1.
PUBL Society of American Foresters Proceedings. 8: 85-90.
ABST Describes methods of classifying forest types in forests of Idaho, Montana, and eastern Washington. Four types are discussed—temporary, climax, cover, and physical.
KEYW Forest types, climax type, cover type, physical type.

506 AUTH Rockwell, F. I.
DATE 1916
TITL White pine in four northwestern States estimated at 27,970,000,000 feet.
PUBL West Coast Lumberman. 31(360): 20-21.
ABST Tabulates the board feet of white pine in Washington, Oregon, Idaho, and Montana. Lists the yield of various diameters of white pine per acre.
KEYW Merchantable stand, board feet by state, board feet per acre by diameter.

507 AUTH Rockwell, F. I.
DATE 1920
TITL Diseases: *Pinus monticola*.
PUBL Unpublished manuscript (carbon copy) on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Science Laboratory, Moscow, ID. 22 p.
ABST Diseases of western white pine are briefly described as they are induced by various external injuries, atmospheric influences, soil, cryptogamic plants, and animals.
KEYW Disease survey, fire, blue stain, soil conditions, frost injury, high temperatures, drought, bark scorching, snow damage, lightning, *Trametes pini, Polyporus sulphureus, Fomes pinicola, Fomes laricis, Polyporus schweinitzii, Fomes annosus, Armillaria mellea, Lophodermium pinastri,* lichen damage, *Usnea barbata, Usnea longissima, Alectroia fremontii,* yellow bellied sapsucker, rednaped sapsucker, *Rodentia*.

508 AUTH Roff, J. W., Shen, H.
DATE 1959
TITL Loss in stiffness evaluates decay resistance of wood treated with copper naphthenate.
PUBL Forest Products Journal. 9: 262-265.
ABST Inception of wood decay was measured by loss in stiffness of western white pine beams exposed to wood-destroying fungi. Results of bending tests on material treated with copper naphthenate showed that a concentration of 5 percent by weight of copper applied by dipping inhibited most test organisms. Reduction in strength, indicated by increased deflection, showed failure of treatments often when there was no weight loss in the wood.
KEYW Decay resistance, copper naphthenate, deflection, wood decay.

509 AUTH Rogers, E. C.
DATE 1917
TITL Delayed germination among five-needled pines with particular reference to *Pinus monticola* Dougl.
PUBL Ithaca, NY: Cornell University. 73 p. M.S. thesis.
ABST The use of sulfuric acid, potassium permanganate, or hydrogen peroxide did not increase germination. Seed collection date did not influence germinative energy. Cutting the seed coat of the radicle end resulted in prompt germination of 20 to 50 percent of the seed.
KEYW Seed germination, delayed germination.

510 AUTH Rogers, J. D.
DATE 1967
TITL A study of fungi associated with the decomposition of coniferous litter.
PUBL Pullman, WA: Washington State University. Ph.D. thesis. [Dissertation abstracts 27b: 2959.]
ABST The kinds and successions of fungi associated with decomposition of litter under *Abies grandis, Pinus monticola,* and *P. ponderosa* on sites located in Latah County, ID, were studied. A total of 151 species of fungi were isolated from A0 and A1 soil horizon materials. These included: 125 *Fungi imperfecti*, 13 *Ascomycetes,* and 10 species of *Phycomycetes*.
KEYW Litter, soil fungi, *Fungi imperfecti, Ascomycetes, Phycomycetes*.

511 AUTH Rothermel, R. C., Anderson, H. E.
DATE 1966
TITL Fire spread characteristics determined in the laboratory.
PUBL Research Paper INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service,

Intermountain Forest and Range Experiment Station. 34 p.
ABST Fire spread characteristics of western white pine and ponderosa pine needles at different moisture levels and different wind velocities were tested under controlled conditions. Some conclusions were: (1) As wind increased, the fire spread at an increasing rate; (2) the fire was carried in the surface fuel particles; (3) flame depth increased and vertical depth of burn decreased as windspeed increased; (4) in the absence of wind, rate of spread decreased linearly as fuel moisture increased.
KEYW Fire spread, fuel moisture, wind, fuel beds, flame size, pine needles.

12 AUTH Ryker, R. A., Pfister, R. D.
DATE 1967
TITL Thinning and fertilizing increase growth in a western white pine seed production area.
PUBL Research Note INT-56. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Thinning increased diameter growth of 40-year-old western white pine trees by 39 percent. Fertilizing with N and NPK had no effect in unthinned plots, but caused an additional increase of 36 percent in diameter growth in thinned plots. Height growth was not affected by thinning and fertilizing.
KEYW Thinning, fertilization, seed production, diameter growth, height growth.

13 AUTH Saho, H.
DATE 1972
TITL White pines of Japan.
PUBL In: Biology of rust resistance in forest trees. Miscellaneous Publication 1221. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 179-199.
ABST Native *Pinus pentaphylla* from cool, rocky sites of northern Japan and *P. himekomatsu* from similar mountainous sites to the south both exhibit slower growth but higher needle-rust and rodent-damage resistance than introduced *P. strobus*. The often dwarf and very slow-growing *P. pumila* occupies mountaintop sites throughout northern and central Japan and is quite resistant to needle rusts. *P. koraiensis*, limited almost entirely to the central mountains of Honshu, exhibits growth slightly better than *P. pentaphylla*, but still well below that of *P. strobus*. It is highly susceptible to needle rusts. *Pinus strobus* is the preferred white pine introduction, but if vole populations are high, control of these rodents is required. Only limited information was available on *P. monticola, P. griffithii, P. albicaulis, P. flexilis*, and *P. lambertiana*.
KEYW Native Japanese white pine, needle rust resistance, growth.

514 AUTH Santamour, F. S., Jr.
DATE 1960
TITL New chromosome counts in *Pinus* and *Picea*.
PUBL Silvae Genetica. 9: 87-88.
ABST Chromosome counts made with endosperm (female gametophyte) tissue showed a chromosome number of n=12 for *Pinus monticola* and other haploxylon pines.
KEYW Cytology, chromosome count.

515 AUTH Santamour, F. S., Jr.
DATE 1965
TITL Insect-induced crystallization of white pine resins. I. White-pine weevil.
PUBL Research Note NE-38. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.
ABST Shoot oleoresins of *P. monticola* were readily crystallized in the presence of crushed heads of weevil larvae. The relationship between weevil-induced resin crystallization and susceptibility to weevil attack is not clear.
KEYW White-pine weevil, crystallization, oleoresin, monoterpenes, weevil larvae, *Pissodes approximatus*, *Pissodes strobi* x *approximatus*, white pine species, white pine hybrids.

516 AUTH Santamour, F. S., Jr.
DATE 1965
TITL Insect-induced crystallization of white pine resins. II. White-pine cone beetle.
PUBL Research Note NE-39. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 5 p.
ABST The resistance of *P. monticola* to insect-induced resin crystallization was not exhibited in the control-pollinated hybrids tested. However, the results suggest that *P. monticola* and *P. peuce* may contribute some degree of resistance to the beetle.
KEYW Oleoresin, crystallization, white pine cone beetle, *Conophthorus coniperda*, resistance.

517 AUTH Satterlund, D. R., Haupt, H. F.
DATE 1967
TITL Snow catch by conifer crowns.
PUBL Water Resources Research. 3: 1035-1039.
ABST Study of interception storage of snow by two species of sapling conifers in northern Idaho revealed that cumulative snow catch follows the classical law of autocatakinetic growth. Interception storage conformed to the law in five storms in which snowfall began while the trees were bare and in two storms in which snow fell while snow from

previous storms persisted on the trees. Several small storms yielded insufficient data to define the appropriate constants, but inspection indicated no serious deviation from the general law.

KEYW Interception, snow, conifer crowns.

518 AUTH Satterlund, D. R., Haupt, H. F.
DATE 1970
TITL The disposition of snow caught by conifer crowns.
PUBL Water Resources Research. 6: 649-652.
ABST Snow interception studies during the warm winters of 1966-67 and 1967-68 in northern Idaho revealed that Douglas-fir and western white pine saplings caught about one-third of the snow that fell in 22 storms. More than 80 percent of the snow initially caught in the crowns ultimately reached the ground by being washed off by subsequent rain, falling by direct mass release, or dripping as melting snow. Only a small portion was lost by evaporation.
KEYW Snow disposition, snow interception, tree crown.

519 AUTH Schafer, E. R., Hyttinen, A., Martin, J. S.
DATE 1960
TITL The groundwood and sulfate pulping of pole-blighted and healthy western white pine.
PUBL Report FPL-2185. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 14 p.
ABST Groundwood and sulfate pulping experiments were made on wood from healthy and pole-blighted western white pine. Pulps of good quality can be produced from both types, although those made from the healthy trees were, on the average, slightly higher in strength than those from the pole-blighted trees.
KEYW Groundwood pulping, sulfate pulping, pole blight, stand composition, physical characteristics, chemical analysis, pulp strength.

520 AUTH Schenk, J. A., Goyer, R. A.
DATE 1967
TITL Cone and seed insects of western white pine in northern Idaho: distribution and seed losses in relation to stand density.
PUBL Journal of Forestry. 65: 186-187.
ABST An adequate seed source is necessary to supply seed for the increasing number of forest plantations being established by public and private agencies in the Western United States. Thus, as the demand for forest tree seed has increased, the effects of insects on its production and collection has become of vital concern. Previous examinations of cones from western white pine plantations indicated that relatively heavier infestations occur in low-density than in high-density stands. The results of a study initiated in 1963 to more fully investigate this relationship are reported here.
KEYW Cone insects, seed insects, *Eucosma rescissoriana, Dioryctria abietella, Conophthorus monticolae.*

521 AUTH Schmidt, W. C., Lotan, J. E.
DATE 1980
TITL Phenology of common forest flora of the Northern Rockies—1928 to 1937.
PUBL Research Paper INT-259. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 20 p.
ABST This paper presents 10 years of phenological observations of common forest flora of the Northern Rockies. Descriptions of important phenological events and earliest, latest, and average dates of their occurrence are included. Phenological data were collected on many National Forests, as well as Yellowstone and Glacier National Parks, at more than 40 locations ranging from eastern Montana to northern Idaho. Summaries include 50 forest species—13 conifers, 22 hardwood trees and shrubs, and 15 herbaceous plants. Six summary tables are used to stratify the phenological information for the above three vegetation groupings both east and west of the Continental Divide. This phenological information has the potential for much practical application where timing of events such as leafing, pollination, cone opening, and others are key to scheduling specific management and research activities.
KEYW Phenological observations, native plants.

522 AUTH Schopmeyer, C. S.
DATE 1938
TITL Brushfield reforestation in the St. Joe National Forest, Idaho.
PUBL Applied Forestry Note 83. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Two reforestation methods (clearing strips with a bulldozer and broadcast burning) are compared. The stock of western white pine planted in 1937 showed nearly 100 percent survival after one growing season on both the burned area and the natural brush. On the stripped area survival was only 82 percent. Seedlings in natural brush did not appear as vigorous as those on the burned area.
KEYW Reforestation, broadcast burning, bulldozer clearing.

523 AUTH Schopmeyer, C. S.
DATE 1939
TITL Direct seeding in the western white pine type.
PUBL Applied Forestry Note 90. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The relative success of these studies is attributed to adequate protection of seed spots against rodents and to the selection of more favorable sites. Fall sowing of seed of all species resulted in average germination of 60 percent; germination of spring sown seed was not more than 25 percent. Spring-sown white pine seed had less than 5 percent germination, probably due to failure of stratification treatment.
KEYW Direct seeding, seed stratification, seed germination, seed spots.

524 AUTH Schopmeyer, C. S.
DATE 1940
TITL Second-year results of direct-seeding experiments in the western white pine type using screens for rodent control.
PUBL Research Note 6. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 7 p.
ABST Results 2 years after sowing demonstrate the possibility of using direct seeding as a method of reforestation in the western white pine type. Cultivation of seed spots previous to sowing results in no better stocking than that obtained by sowing seed in undisturbed mineral soil after removing ashes and duff. Average stocking from fall sowing was 17 percent greater than from spring sowing. The use of conical screens for protection of fall-sown western white pine seed resulted in three times the percentage of successful seed spots.
KEYW Direct seeding, fall sowing, spring sowing.

525 AUTH Schopmeyer, C. S.
DATE 1940
TITL Successful forestation by direct seeding using poisons for rodent control.
PUBL Research Note 1. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Rodent control was obtained by prepoisoning areas to be direct seeded. Poison consisted of hulled sunflower seed treated with thallium sulfate (one part to 100 parts of seed by weight). In addition, seed to be sown was treated with a mixture of 48 percent yellow dextrine, 34 percent plaster of paris, 15 percent cornmeal, and 3 percent strychnine alkaloid. In the small tests described here, this method proved effective, practical, and economical.
KEYW Rodent control, reforestation, direct seeding, planting costs.

526 AUTH Schopmeyer, C. S.
DATE 1940
TITL Survival in forest plantations in the Northern Rocky Mountain Region.
PUBL Journal of Forestry. 38: 16-24.
ABST During the period 1910-37, a total of 1,150 plantations were established on an aggregate area of 93,878 acres in western Montana, northern Idaho, and northeastern Washington. The means of all recorded first-year survival percentages of spring-planted western white pine and ponderosa pine trees are 7 and 10 percent higher, respectively, than those of fall-planted trees of the same species. An analysis of all available first- and third-year survival data on plantations of various age classes of planting stock showed that there are no significant differences in survival between age classes of stock of either western white pine or ponderosa pine. The mean tenth-year survival percentage of 210 plantations distributed over the region on an aggregate area of 29,589 acres is 42 percent.
KEYW Plantation survival, nursery practices, planting practices, spring planting, fall planting.

527 AUTH Schopmeyer, C. S., Helmers, A. E.
DATE 1947
TITL Seeding as a means of reforestation in the Northern Rocky Mountain Region.
PUBL Circular 772. Washington, DC: U.S. Department of Agriculture. 31 p.
ABST These experiments with direct seeding were initiated to develop methods to supplement and increase the flexibility of, or lower the cost of, the reforestation program. Western white pine was successfully spot-sown on freshly burned north-facing slopes and flats within the western white pine type where protection from rodents was provided. Effective control of rodents was attained either by using conical wire screens over seed spots or by spreading poisoned bait 1 week prior to seeding. The number of seedlings established by the spot-sowing method compared favorably with the number of nursery-grown trees established by planting. Fall sowing of western white pine, ponderosa pine, Engelmann spruce, and western redcedar resulted in better initial stocking than spring sowing. Cultivation of seed spots at the time of sowing on burned-over areas did not improve the germination or survival of

western white pine, ponderosa pine, and Engelmann spruce. A single test of broadcast-sown western white pine attained higher stocking than spot-sown white pine.

KEYW Reforestation, spot sowing, broadcast sowing, rodent control, fall sowing, spring sowing, cultivation, direct seeding.

528 AUTH Schubert, G. H.
DATE 1952
TITL Germination of various coniferous seeds after cold storage.
PUBL Research Note PSW-83. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 7 p.
ABST Seeds were air-dried, then stored in airtight containers at 41 °F for periods from 2 to 24 years. They were then stratified in moist sand and peat moss for 60 days at 36 °F. *Pinus monticola* in storage for 16 years had 35 percent germination; that stored for 15 years had 40 percent germination. However, stratification time may not have been sufficient.
KEYW Seeds, cold storage, seed storage, seed germination.

529 AUTH Schubert, G. H.
DATE 1954
TITL Viability of various conifer seeds after cold storage.
PUBL Journal of Forestry. 52: 446-447.
ABST Germination of seeds from 42 species of conifers after prolonged cold storage (41 °F) is summarized. Percentage viability for *Pinus monticola* was: 0-5 years (2 seed lots), 62 percent; 11-20 years (4 seed lots), 20-40 percent.
KEYW Seed viability, seed germination, seed storage.

530 AUTH Seikel, M. K., Hall, S. S., Feldman, L. C., Koeppen, R. C.
DATE 1965
TITL Chemotaxonomy as an aid in differentiating wood of eastern and western white pine.
PUBL American Journal of Botany. 52: 1046-1049.
ABST Heartwoods from *Pinus strobus* (eastern white pine) and *Pinus monticola* (western white pine), which are difficult to distinguish anatomically, can be separated with about 95 percent accuracy by subjecting their acetone extracts to simple paper chromatography. Basically, this differentiation is possible because the relative proportions of certain flavanones vary in the two species, and when these are treated with the chromogenic spray, distinguishing colors are produced at different rates of speed. With *P. strobus*, the characteristic yellowish-orange spot results from higher percentages of cryptostrobin and strobobanksin; the pinkish-red spot, typical of *P. monticola* extract, is due to a preponderance of pinocembrin.
KEYW Heartwood chemicals.

531 AUTH Shaw, C. G., Leaphart, C. D.
DATE 1960
TITL Two serious foliage diseases of western white pine in the Inland Empire.
PUBL Plant Disease Reporter. 44: 655-659.
ABST Two diseases not previously differentiated are reported on western white pine from Idaho. Needle cast, caused by *Hypodermella arcuata* Darker, occurs primarily in the upper crown. Needle blight, with which a species of *Lecanosticta* is associated, is most prevalent in the lower crowns of infected trees. The sequence of development of symptoms and of the associated organisms is outlined for the two diseases.
KEYW Foliage diseases, needle cast, *Hypodermella arcuata*, needle blight, *Lecanosticta*.

532 AUTH Shaw, C. G., Thyr, B. D.
DATE 1962
TITL Observations on diseases of coniferous foliage in the Inland Empire.
PUBL Phytopathology. 52: 365. Abstract.
ABST Among other observations, it is noted that *Hypodermella arcuata*, epidemic in 1959, was less prevalent in 1960. Analysis of weather data indicated a correlation between infection and precipitation during the period of ascosporic discharge in July and August.
KEYW *Hypodermella arcuata*.

533 AUTH Shaw, C. H.
DATE 1916
TITL The vegetation of the Selkirks.
PUBL Botanical Gazette. 61: 477.
ABST This article, compiled from his notes after Dr. Shaw's death, gives an overall summary of the vegetation of the Selkirk Mountains. Dr. Shaw listed *Pinus monticola* as a principal species of the area, but as less prominent in an early phase of reforestation after a burn. He stated that nowhere was it very abundant, but it was becoming a valuable timber tree in the hemlock district.
KEYW Vegetation classification, Selkirk Mountains, reforestation.

534 AUTH Shifrine, M., Phaff, H. J.
DATE 1956
TITL The association of yeasts with certain bark beetles.
PUBL Mycologia. 48(1): 41-55.

ABST This paper summarizes a survey of the yeasts associated internally with various species of the bark beetle genera *Dendroctonus* and *Ips*, collected from five different species of pine. A total of 169 yeasts were identified. *Saccharomyces pini* is the most common yeast associate of *Dendroctonus brevicomis*, and *Candida silvicula* is most prevalent in *Ips oregoni*. All three major species of yeasts were isolated from *P. monticola*. Typical physiological properties of the yeast isolates are discussed.
KEYW Bark beetles, host trees, yeasts, *Dendroctonus*, *Ips*.

535 AUTH Simeone, J. B., MacAndrews, A. H.
DATE 1955
TITL The old house borer in New York State.
PUBL Journal of Economic Entomology. 48(6): 753-754.
ABST The establishment of the old house borer (*Hylotrupes bajulus*) as a serious pest of wood structures in Northeastern United States has been of growing concern. Since 1900, several collections of the old house borer have been made in New York State by various workers. This article reports some additional records which were communicated to the authors.
KEYW *Hylotrupes bajulus*, insect pest, wood structures.

536 AUTH Skeels, D.
DATE 1927
TITL Compulsory slash disposal in Montana.
PUBL The Timberman. 28: 178-182.
ABST A new law to cover the disposal of slash was considered in Montana. This article covers the various needs for a law, the various methods of slash disposal, laws in Idaho, and experimental laws.
KEYW Slash disposal, forest legislation.

537 AUTH Smith, J. H. G., Ker, J. W.
DATE 1957
TITL Timber volume depends on D^2H.
PUBL British Columbia Lumberman. 1957(9): 28-30.
ABST Combined-variable equations are presented as a simplified alternative to the original logarithmic tree volume relationships used to estimate cubic foot volume of commercial British Columbia species.
KEYW Cubic foot volume tables, combined variable formula.

538 AUTH Smith, R. H.
DATE 1963
TITL Toxicity of pine resin vapors to three species of *Dendroctonus* bark beetles.
PUBL Journal of Economic Entomology. 56: 827-831.
ABST The vapor toxicity of saturated resin vapors of both host and nonhost pines was determined for three species of *Dendroctonus*: *D. brevicomis, D. ponderosae,* and *D. jeffreyi*. Results with hard pines substantiate the hypothesis that bark beetles of this genus can tolerate saturated vapors of host resin but not of nonhost resin, suggesting that resin is a determining factor in host specificity. Results with soft pines do not substantiate the hypothesis, suggesting that other properties of resin or nonresinous characteristics of these pines determine host specificity. A delayed effect in many tests with hard pine host resin suggests that even host resins can be deleterious under certain conditions. Variable results were obtained with hybrid pines. The overall results suggest that resin in some capacity may be an important factor in host resistance.
KEYW *Dendroctonus brevicomis, Dendroctonus ponderosae, Dendroctonus jeffreyi,* resin vapor toxicity.

539 AUTH Smythge, R. V., Coppel, H. C., Lipton, S. H., Strong, F. M.
DATE 1967
TITL Chemical studies of attractants with *Reticulitermes flavipes* and *R. virginicus*.
PUBL Journal of Economic Entomology. 60: 228-233.
ABST Both the eastern subterranean termite (*Reticulitermes flavipes*) and *R. virginicus* have an abdominal gland which secretes a compound inducing trail-following and other attractant behavior in either species. Purification of the compound carried through one gas-liquid chromatographic run gave a product active at 0.1 mg. Western white pine rotted by the fungus *Lenzites trabea* produced trail-following with material from 100 micrograms of wood per mL of test solution. On a weight basis, *L. trabea*-rotted wood is approximately 20 times as rich a source of attractant as the termites themselves. When the product from wood was gas chromatographed, the active region corresponded in retention time to that found for the gland substance.
KEYW Attractants, *Reticulitermes flavipes, Reticulitermes virginicus, Lenzites trabea.*

540 AUTH Snellgrove, T. A., Fahey, T. D.
DATE 1977
TITL Market values and problems associated with utilization of dead timber.
PUBL Forest Products Journal. 27(10): 74-79.
ABST Dead timber suffers a series of incremental losses: (1) logging and handling losses in the

woods and mill yard, (2) decreased lumber volume from logs sawed, and (3) degrade of lumber due to deterioration defects. Dollars per hundred cubic feet of gross tree volume is used to express value losses. A number of factors can affect utilization of dead timber. These include inherent bias against utilization, handling problems created by increased breakage, manufacturing problems in mills, and market considerations.

KEYW Dead timber, utilization, product potential, losses, economic opportunity.

541 AUTH Snellgrove, T. A., Plank, M. E., Lane, P. H.

DATE 1970

TITL An improved system for estimating the value of western white pine.

PUBL Research Paper PNW-166. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 19 p.

ABST This report describes an improved system for estimating the lumber selling value or volume of western white pine sawtimber. The model developed contains six tree characteristics: (1) tree diameter, (2) tree height, (3) height to the first live limb, (4) the number of limb-free and defect-free faces in the butt 16-foot log, (5) diameter of the largest limb in the butt 16-foot log, and (6) total tree defect percent. The prediction equation, using those six characteristics, accounts for 94 percent of the variation in tree value and 95 percent of the variation in lumber tally volume as measured by the regression values. The system is faster and more objective than log grading and has the additional advantage of eliminating grouping error by being a continuous predictor.

KEYW Tree value estimates, tree volume estimates, grading system.

542 AUTH Snyder, G. G., Haupt, H. F., Belt, G. H.

DATE 1975

TITL Clearcutting and burning slash alter quality of stream water in northern Idaho.

PUBL Research Paper INT-168. Ogden, UT: U.S. Department of Agriculture. Forest Service, Intermountain Forest and Range Experiment Station. 34 p.

ABST Reports the results of a 21-month study of changes in the quality of streamwater after clear felling and prescribed burning of slash on three areas in a *Pinus monticola / Thuja plicata / Pseudotsuga menziesii / Larix occidentalis* forest. Significant increases in pH, electrical conductivity, turbidity, suspended solids, HCO_3, SO_4, K, Ca, and Mg occurred in sections of the streams within the clear-felled areas, but changes between stations above and below the clear-felled areas were within the limits of the U.S. Public Health Service standards for drinking water.

KEYW Clearcut, water quality.

543 AUTH Soles, R. L., Gerhold, H. D.

DATE 1970

TITL Development and evaluation of methods for selecting pines for resistance to the white-pine weevil.

PUBL School of Forestry Research Briefs. University Park, PA: Pennsylvania State University; 4(4): 49-52.

ABST Attack by weevils was compared between eastern white pine and western white pine, a resistant host. Results suggest that resistance mechanisms of western white pine either inhibit the weevils from traveling to the trees or induce them to leave. No differences after attack were noted.

KEYW Resistance weevil.

544 AUTH Soles, R. L., Gerhold, H. D., Palpant, E. H.

DATE 1969

TITL Testing white pine seedlings for weevil resistance.

PUBL In: 2d FAO/IUFRO world consultation on forest tree breeding; FO-FTB-69-5/9. 4 p.

ABST Experiments were conducted to determine the feasibility of screening small pine seedlings in cages for resistance to the white-pine weevil, *Pissodes strobi*. The weevils showed normal host attack behavior in all stages of their life cycle and were able to discriminate differences in susceptibility among various provenances of eastern white pine (*Pinus strobus*) and among eastern white pine, western white pine (*Pinus monticola*), and Himalayan white pine (*Pinus griffithii*). Varying intensities of selection against seedlings susceptible to weevil attack were obtained by manipulation of weevil population density, weevil population sex ratio, and date of exposure. The results show that caged white pine seedlings can be successfully tested for their weevil resistance when between 2 and 5 years old. A population density of about one male plus one female per tree, or of two females per tree, should be introduced into the cages containing trees soon after the weevils become active in the spring. An exposure period of 2 weeks should yield differences among seedlings in adult feeding and larval-caused leader mortality that permits elimination of 25 percent of the seedlings. The seedlings may be exposed to weevil attack each year for years, and the more resistant seedlings can then be outplanted for further resistance evaluations.

KEYW Weevil resistance, insect resistance, *Pissodes strobi*.

5 AUTH Soles, R. L., Gerhold, H. D., Palpant, E. H.
DATE 1970
TITL Resistance of western white pine to white-pine weevil.
PUBL Journal of Forestry. 68: 766-768.
ABST Western white pine is resistant to attack by the white pine weevil (*Pissodes strobi*). Adult weevils were caged on trees of eastern white pine and western white pine; indices of attack were used to determine which stages of the life cycle of the weevil were affected by resistance mechanisms. Adult weevil mortality was negligible for both species; the numbers of feeding cavities on *P. monticola* were greater than on *P. strobus*. Numbers of adult emergence holes and leader mortality were similar for both species. The results suggest that resistance mechanisms of *P. monticola* either inhibit the weevils from traveling to the trees or induce them to leave.
KEYW White pine weevil, *Pissodes strobi*, weevil resistance, leader mortality.

46 AUTH Spokesman Review.
DATE 1952
TITL Blight's threat still mystery.
PUBL The Spokesman Review. 1952 June 17: p. 5, col. 1.
ABST An interview with C. A. Wellner concerning pole blight.
KEYW Pole blight.

47 AUTH Squillace, A. E.
DATE 1952
TITL Opportunities for forest genetics research in the Northern Rocky Mountain Region.
PUBL Montana Academy of Science Proceedings. 11: 3-7.
ABST The current project with western white pine is the blister-rust-resistant white pine breeding project, a cooperative venture of the Bureau of Entomology and Plant Quarantine and the United States Forest Service. Fifty-nine trees with apparent resistance to blister rust have been located in northern Idaho and are being crossed by controlled pollination, or vegetatively propagated. Hybridization tests include *Pinus monticola* x *P. strobus* and *P. monticola* x *P. griffithii*.
KEYW Blister rust resistance, vegetative propagation, hybridization, *Pinus monticola* x *P. strobus*, *Pinus monticola* x *P. griffithii*.

48 AUTH Squillace, A. E.
DATE 1954
TITL Forest genetics research in the Northern Rocky Mountain Region.
PUBL Journal of Forestry. 52: 691-692.
ABST The following investigations concern western white pine: blister-rust-resistant western white pine; investigations of self-fertility and self-compatibility in western white pine; vegetative propagation techniques; hybridization and field testing of hybrids; development of a strain of ponderosa pine suitable for planting as a substitute for western white pine.
KEYW Self fertility, self compatibility, vegetative propagation, hybridization.

549 AUTH Squillace, A. E.
DATE 1957
TITL Variations in cone properties, seed yield and seed weight in western white pine when pollination is controlled.
PUBL Bulletin 5. Missoula, MT: Montana State University, School of Forestry. 16 p.
ABST Two tests were conducted to study factors associated with within-tree variation in cone characteristics, seed yield, and seed weight in western white pine, during the period 1952-54. In these tests 149 cones were produced through specially designed, intraspecific controlled pollinations on eight trees growing in northern Idaho. Within-tree variations in cone length and average seed weight by cones were found to be associated with factors peculiar to the particular shoots on which the cones are borne. Seeds borne on shoots in the upper and outer crown and on the south and west sides tended to be heavier than those in opposing portions of the crown. Cones borne on the more fruitful shoots tended to be longer and contained heavier seeds than those on the less fruitful shoots. Metaxenial effects upon the ratio of cone-scale width to scale length were rather definitely shown. Similar effects were also noted upon cone length, ratio of average scale size to cone length, and seed weight, but they did not occur in a sufficient number of cases, or the evidences were not strong enough, to establish conclusively such effects. The putative metaxenial effects were usually small and often easily obscured by environmental influences. Sound seed yield was often directly correlated with cone length. Average seed weight by cones was directly correlated with cone length and average scale size and inversely correlated with relative sound seed yield (ratio of sound seed yield to cone length). It was shown that pollen source can affect seed yield. Thus pollen can also affect seed weight indirectly through its influence upon seed yield.
KEYW Cone properties, seed yield, pollination, seed weight.

550 AUTH Squillace, A. E., Bingham, R. T.
DATE 1954
TITL Breeding for improved growth rate and timber quality in western white pine.
PUBL Journal of Forestry. 52: 656-661.
ABST A cooperative project designed to breed blister-rust resistant and otherwise superior western white pine is now in its fifth year of activity. This report discusses phases involving intraspecies breeding for improved growth rate and timber quality. It describes the work being done and presents some early results. Growth rates of numerous progenies produced by controlled pollinations were statistically correlated with growth rates of their parents. Thus, experimental control was more complete than in many previous investigations on heritable vigor.
KEYW Height growth variation, phenotypic variation, branching habit, genotypic variation, disease resistance, racial variation.

551 AUTH Squillace, A. E., Bingham, R. T.
DATE 1954
TITL Forest genetics research in the Northern Rocky Mountain Region.
PUBL Journal of Forestry. 52: 691-692.
ABST The article summarizes all current forest genetics research in the Northern Rocky Mountain Region. Research concerning western white pine includes blister rust resistance, self-fertility, self-compatibility, and vegetative propagation techniques.
KEYW Disease resistance, inheritance, height growth, self fertility, self compatibility, vegetative propagation, hybridization, *Pinus strobus* x *P. monticola*.

552 AUTH Squillace, A. E., Bingham, R. T.
DATE 1958
TITL Localized ecotypic variation in western white pine.
PUBL Forest Science. 4: 20-34.
ABST Controlled breeding work with *Pinus monticola* conducted during the years 1950-55 has produced evidence that ecotypes of a very local nature exist. The evidence is based upon 166 controlled pollinations made among 45 trees (selected for apparent resistance to blister rust) growing in eight areas. In addition to the controlled pollinations, wind-pollinated seed were collected from the selections and from other nonresistant trees growing on the different areas. Certain selection areas, though in one case as little as one-half mile apart, represented considerably different environments. Growth rates of the parent trees and their progenies up to 4 years of age were measured. Seeds of 116 progenies were subjected to osmotic pressure tests, and foliage dry matter content was measured on 15 progenies. Results were as follows: (1) Progenies of trees from the better sites (moist, low elevations) grew more rapidly, on good planting sites, than those of trees from poorer sites (dry slopes or high elevations). (2) Progenies of trees from high elevations grew relatively more rapidly when outplanted at a high elevation than progenies of low elevation sources. (3) Progenies of trees from high elevations had more foliage dry matter content than those of low elevations. (4) Progeny seeds from different selection areas exhibited differences in apparent osmotic pressure. Where topography is highly variable and growing season moisture is a critical factor, selection pressures such as seedling establishment and growth rate discriminate against infiltration of genes from trees adapted to radically different although adjacent sites.
KEYW Ecotypic variation, osmotic pressure, foliage dry matter.

553 AUTH Squillace, A. E., Bingham, R. T.
DATE 1958
TITL Selective fertilization in *Pinus monticola* Dougl.
PUBL Silvae Genetica. 7: 188-196.
ABST Three tests were made specifically to determine whether any selective fertilization effects occurred when pollen of a given western white pine was in competition with that of another tree of the same species. In each test, matings were made between two trees, a and b, as follows: axa, axb, and ax(a+b). In the latter type of mating, pollens from the two parents (a+b) were mixed in equal proportions. Differences in early growth rate (length of epicotyl and total height) among the resulting 1-year-old progenies from matings within tests were used as the main basis for estimating the degree of selective fertilization. Other factors such as mean cotyledon number and seed yield had limited usefulness. In a moderately self-fertile tree crossing exceeded selfing. In a highly self-fertile tree, crossing exceeded selfing when its own pollen was mixed with that from one tree, while the reverse was true when its own pollen was mixed with that of another tree. Results of the tests, along with less reliable but more extensive determinations of the growth rate of wind-pollinated versus self- and cross-pollinated seedlings produced earlier, suggest that in stands under natural pollination conditions crossing largely exceeds selfing.
KEYW Selective fertilization, pollination.

554 AUTH Squillace, A. E., Bingham, R. T., Namkoong, G., Robinson, H. F.

DATE 1967
TITL Heritability of juvenile growth rate and expected gain from selection in western white pine.
PUBL Silvae Genetica. 16: 1-6.
ABST Materials consisted of sixty-one 4-year-old full-sib progenies produced from somewhat random matings among 21 parents. Progenies were grown at each of three localities in randomized blocks, using row-plots and three replications. Parental data consisted of average height growth during the last 10 years, adjusted for differences in age, and local site conditions. Progeny data used was fourth-year height increment. Narrow sense heritabilities, computed separately for each locality, averaged about 7 percent. For the combined analysis, they were only slightly less, indicating low environmental interaction in these data. Expected genetic gains were computed for several hypothetical breeding programs by using statistics obtained from the experimental interaction in these data. Results showed that appreciable genetic gains are possible in spite of the low heritability. Although other factors, not studied here, need to be considered in planning a breeding program, the results reported here suggest desirability of using a combination of phenotypic selection and progeny testing.
KEYW Heritability, juvenile growth rate, selection gain, height increment.

555 AUTH Stage, A. R.
DATE 1973
TITL Prognosis Model for stand development.
PUBL Research Paper INT-137. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 32 p.
ABST This paper describes a set of computer programs for combining quantitative silvicultural knowledge with past growth data from a sampled stand to make a prognosis of the course of development that the forest stand is expected to follow under alternative management prescriptions. An important design criterion of this procedure is that the Prognosis Model should apply to stands containing any mixture of species or age and size classes that grow as a community. The model simulates the deviation-amplifying aspect of the growth process by a unique procedure for introducing the stochastic elements in a deterministic computing algorithm. The growth rates predicted by the built-in models for diameter change are compared to the actual past growth of the sample trees to calibrate these models for the particular stand for which the prognosis is to be computed. Selection of trees to be cut at any period can utilize a variety of tree characters to emulate a wide range of silvicultural prescriptions.
KEYW Prognosis Model, growth rate, silvicultural prescriptions.

556 AUTH Steele, R., Arno, S. F., Pfister, R. D.
DATE 1976
TITL Preliminary forest habitat types of the Nezperce National Forest.
PUBL Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 71 p. [Mimeographed report.]
ABST The habitat types of the Nez Perce National Forest of north-central Idaho are described.
KEYW Habitat type.

557 AUTH Stein, W. I.
DATE 1964
TITL Seedspotting—revival of an old technique.
PUBL In: Western Reforestation Coordinating Committee annual meeting proceedings. p. 18-20.
ABST Discusses pros and cons of seed spotting as a replacement for broadcast seeding. Indicates that success with western white pine has been somewhat lower than sugar pine, the most successful species.
KEYW Seed spot, reforestation.

558 AUTH Steinhoff, R. J.
DATE 1972
TITL White pines of western North America and Central America.
PUBL In: Biology of rust resistance in forest trees. Miscellaneous Publication No. 1221. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 215-232.
ABST Six species of white pines (section *Strobus*, subgenus *strobus*) are native to western North America and Central America. All of these species are rather widely distributed with one or more species occurring in most of the major mountain ranges. Although any of the species may occur in pure stands, they usually are found mixed with several other coniferous species. Three of the species, *P. ayacahuite, P. lambertiana,* and *P. monticola*, are commercially important and a fourth, *P. strobiformis*, is harvested, but on a much smaller scale. Numerous efforts have been made throughout the world to cross these species with other white pines. Several of the resulting hybrid combinations show promise for a variety of uses and for planting in areas where there are few or no native white pines.
KEYW White pines, distribution, mixed stands, commercial importance.

559 AUTH Steinhoff, R. J.
DATE 1974
TITL Inheritance of cone color in *Pinus monticola*.
PUBL Heredity. 65: 60-61.
ABST Results indicate that the presence or absence of purple coloration in *Pinus monticola* cones is conditioned by a single gene having two alleles. Trees classified on the basis of several crosses as being homozygous or heterozygous for the allele promoting purple coloration had cones on which the amounts of purple and green varied; trees homozygous for the alternate allele had yellow-green cones on which there were no traces of purple.
KEYW Cone color.

560 AUTH Steinhoff, R. J.
DATE 1979
TITL Variation in early growth of western white pine in north Idaho.
PUBL Research Paper INT-222. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.
ABST In nursery and field tests representing five different studies, most of the variation in height growth or other traits in any one test area was among seedlings within family plots. Of the usable genetic variation in those traits, most (60-90 percent) was related to differences among the parent trees within stands. The remaining genetic variation was spread among geographic areas, elevational zones, or stands within these categories. When differences among the latter categories were significant, usually no pattern in the variation was apparent. Thus, although seedlings within families and family means within stands vary considerably, the lack of differences among stand means of those for broader geographic areas, and the absence of distinct variation patterns suggests that inland western white pine is fairly uniform. However, seedlings from high-elevation parents (generally 1,375 m or higher) were significantly shorter than those of low- and mid-elevation parents in some low- or mid-elevation tests. Even when elevational effects were not significant very few high-elevation families were among the tallest. Growth results to date indicate that only two seed zones are needed in northern Idaho—a low zone and a high zone generally separated at 1,375 m. Within the lower zone, trees with good growth potential can be found in nearly all stands.
KEYW Ecotypic variation, provenance test, geographical variation.

561 AUTH Steinhoff, R. J.
DATE 1981
TITL Survival and height growth of coastal and interior western white pine saplings in north Idaho.
PUBL Research Note INT-303. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Western white pine saplings from the Olympic Peninsula of Washington and from northern Idaho sources planted together in northern Idaho did not differ in their survival rates. There has been no visual evidence of freezing injury to either group. At age 12, height of the coastal saplings generally falls within the height range for north Idaho saplings. The findings lend support to earlier results, which indicated that most of the variation in northern Idaho white pines is found within, rather than between, populations.
KEYW Geographic variation, provenance trials, height growth.

562 AUTH Steinhoff, R. J., Hoff, R. J.
DATE 1971
TITL Estimates of the heritability of height growth in western white pine based on parent-progeny relationships.
PUBL Silvae Genetica. 20: 141-143.
ABST Heritability estimates for periodic annual height growth were computed from regression and correlation coefficients of progeny growth on male parent, female parent, and mid-parent. The average for the various estimates increased by $1\text{-}^1/_2$ times as the growth rate of the progenies approximately doubled. It appears that most of the increase in the estimates is due to the scaling effect of the increased growth rather than to shifts among the individual progenies. Actual growth increases calculated for a hypothetical selection and breeding program compared closely to predicted values.
KEYW Height growth, heritability.

563 AUTH Steinhoff, R. J., Hoff, R. J.
DATE 1972
TITL Chilling requirements for breaking dormancy of western white pine seedlings.
PUBL Research Note INT-153. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.
ABST One- and 2-year-old western white pine seedlings representative of five full-sib families were artificially chilled at 40 °F from 0 to 14 and from 8 to 20 weeks, respectively. After chilling, the seedlings were placed in a growth chamber and exposed to a 16-hour photoperiod and a 70 to 50 °F temperature

regime. Chilling for at least 14 weeks was necessary for seedlings to approach maximal shoot elongation.

KEYW Dormancy, chilling requirements.

564 AUTH Steinhoff, R. J., Joyce, D. G., Fins, L.
DATE 1983
TITL Isozyme variation in *Pinus monticola*.
PUBL Canadian Journal of Forest Research. 13(6): 1122-1132.
ABST Seeds from 28 stands representing most of the range of *Pinus monticola* were analyzed for electrophoretically demonstrable variation in 10 proteins encoded by 12 genetic loci. On the average, 65 percent of the loci per stand were polymorphic and expected heterozygosity of offspring was 18 percent. The populations could be assigned to two geographic groups, a broad northern one and a rather restricted southern one. The southern group consisted of populations from the Sierra Nevada and southern Cascade Mountains in northern California and from the Warner Mountains in south-central Oregon. Collections from stands in the central and southern Oregon Cascades and the Siskiyou Mountains of northwestern California were more nearly like the northern stands but exhibited some characteristics indicative of a transition area between the Sierra and northern types.
KEYW Isozymes, electrophoresis, geographic variation.

565 AUTH Stephan, B. R.
DATE 1974
TITL Geographic variation of *Pinus strobus* on the basis of first results of field trials in lower Saxony.
PUBL Silvae Genetica. 23(6): 214-220.
ABST *Pinus strobus* field trials in lower Saxony showed that height was negatively correlated with provenance latitude. One provenance of *P. monticola* and two provenances of *P. wallichiana* were compared with *P. strobus* and found to have only 85 percent and 40 percent of the average height, respectively.
KEYW Eastern white pine, differences between provenances, growth rate, mortality, blister rust infections, dwarf plants.

566 AUTH Stewart, M.
DATE 1966
TITL Cost study of partial cutting treatments in interior wet belt of British Columbia.
PUBL Research Note 32. Victoria, BC: British Columbia Forest Service. 22 p.
ABST A 95-year-old stand was subjected to seven cutting treatments to compare, on a commercial scale, a number of different selection principles when incorporated in a partial cut. The stand was composed of Douglas-fir (45-80 percent), western redcedar (20.0 percent), western larch (13.4 percent), western white pine (13.4 percent), Engelmann spruce (5.6 percent), and western hemlock (1.8 percent). It was concluded that the commonly used diameter limit combination of 16 inches d.b.h. for white pine, 12 inches for cedar, and 14 inches for other species does in fact give the logger maximum return for his money.
KEYW Partial cutting, cost study, poles, selection, mixed stand, logs.

567 AUTH Stout, A. W.
DATE 1960
TITL Storage-caused defects in Idaho white pine logs.
PUBL Research Note 2.112. Portland, OR: Western Pine Association. 4 p.
ABST Blue stain was found to be the major degrading factor in stored logs. Twenty percent of the lumber from one sampling of cold-decked logs carried stain, 6 percent being stained to the point of degrade that totaled $3.60/thousand bd ft loss. Checking and worm-hole damage increased the loss to $6.67/thousand bd ft. The bundled-in-water storage loss was negligible, but those logs entirely above water suffered stain losses amounting to $2.60/thousand bd ft.
KEYW Storage caused defects, blue stain, checking, worm-hole damage.

568 AUTH Stutz, R. E., Stout, A. W.
DATE 1957
TITL The nature of the chemical brown stains in lumber from the western pines.
PUBL Plant Physiology. 32: 13. Abstract.
ABST The chemical brown stain sometimes found in lumber from *Pinus ponderosa, P. lambertiana,* and *P. monticola* has previously been thought to be of a nonbiological origin. The authors demonstrated that the stain, which is restricted to the sapwood of old pond-stored logs, is caused by a microorganism that acts mainly on the ray cells. The presence of these bacteria is first indicated by the sour odor of the green lumber and the tanniclike pigment which may be found after kiln-drying. The brown color disappears in the advanced stages as the porosity and level of volatile acids increases.
KEYW Chemical brown stain, microorganism, sapwood, heartwood.

569 AUTH Sudworth, G. B.
DATE 1917
TITL Western white pine.

PUBL In: The pine trees of the Rocky Mountain Region. Bulletin 460. Washington, DC: U.S. Department of Agriculture. p. 4-6.
ABST Gives a general description of western white pine including early history, distinguishing characteristics, occurrence and habits, and longevity.
KEYW General description, longevity, history.

570 AUTH Sutherland, J. R.
DATE 1979
TITL The pathogenic fungus *Caloscypha fulgens* in stored conifer seeds in British Columbia and relation of its incidence to ground and squirrel-cache collected cones.
PUBL Canadian Journal of Forest Research 9(1): 129-132.
ABST Stored seeds were assayed for the seed-borne fungus *Caloscypha fulgens*. There was no relationship between incidence of infested seedlots and year of cone collection or geographic origin. Overall, squirrel cache-collected cones had the highest incidence, and slash-picked cones the lowest incidence, of *C. fulgens*-infested seedlots. The percentage of diseased seeds within infested seed lots was unrelated to the origin of ground-picked cones.
KEYW Conifer seeds, *Caloscypha fulgens*, pathogenic fungus, ground-collected cones, squirrel cache-collected cones.

571 AUTH Thyr, B. D.
DATE 1964
TITL Three fungi associated with foliage diseases of western pines.
PUBL Pullman, WA: Washington State University. 96 p. Ph.D. thesis.
ABST Three fungi (*Hypodermella arcuata, Lecanosticta* sp., and *Dothiatroma pini* var *linearis* var *nova*) associated with foliage diseases of western pines (*Pinus monticola, P. contorta,* and *P. ponderosa*) were investigated. Data from a needle cast bagging experiment indicate *Hypodermella arcuata* infects western white pine foliage mostly between mid-June and mid-July. Epiphytotics of needle cast are directly correlated with abundant rainfall during June and July of the preceding summer. Data from a needle blight bagging experiment indicate *Lecanosticta* infects western white pine foliage mostly during early June. Significance of needle blight is reduced to no more than a possible predisposing agent.
KEYW *Hypodermella arcuata, Dothistroma pini, Actinothyrium marginatum, Leptostroma decipieus, Lecanosticta acicola,* needle blight, needle cast, pine bark aphid.

572 AUTH Thyr, B. D., Shaw, C. G.
DATE 1966
TITL Ontogeny of the needle cast fungus, *Hypodermella arcuata*.
PUBL Mycologia. 58: 192-200.
ABST Hyphae of *Hypodermella arcuata* penetrate the endodermis of *Pinus monticola* and tissues external to it. Stromatic tissue developing between the host's hypodermis and epidermis constitutes the first macroscopic sign of the fungus and is visible on needles in April or May the year following infection. Differentiation begins in the upper half of the stoma with an orientation of hyphae perpendicular to the dermal tissues. These hyphae appear at maturity to be paraphyses, but initially are apically attached to the upper stromatic layer. Pseudoparenchymatous tissue surrounding the centrum becomes compressed forming a wall. Unitunicate asci develop from the basal pseudoparenchymatous tissue. The host's epidermis and the upper stromatic tissue of the fungus remain over the hymenium until maturity, at which time they split almost completely exposing the hymenium. Eight sheathed uninucleate ascospores develop in each ascus and are forcibly ejected when the mature ascocarp absorbs water. Ascospores germinate from either end by short germ tubes, form appressoria, and probably penetrate the needle directly through the cuticle and epidermis.
KEYW Ontogeny, needle cast, *Hypodermella arcuata.*

573 AUTH Timber of Canada.
DATE 1946
TITL Paint and wood work together.
PUBL Timber of Canada. 7(2): 54, 57, 59.
ABST Proper paint performance depends on surface material, correct construction, and paint quality. Factors affecting suitability of materials (wood surfaces) and paint are discussed.
KEYW Summer wood, spring wood, knots, lumber grade, paint failures, paintability.

574 AUTH Tinsley, S. L.
DATE 1938
TITL Direct seeding—a revival.
PUBL Journal of Forestry. 37: 888-890.
ABST Since the large-scale failure of direct seeding in the early days of forestry in the United States, artificial reforestation has been considered almost entirely in terms of planting. In this article, the author protests the abandonment of direct seeding while still in its infancy and presents the results of experiments conducted to determine the factors

affecting success and failure in direct seeding.
KEYW Artificial reforestation, direct seeding, seed spot method, stratification, rodent protection.

75 AUTH Townsend, A. M.
DATE 1969
TITL Physiological, morphological, and biochemical variation in western white pine (*Pinus monticola* Dougl.) seedlings from different altitudinal seed sources in Idaho.
PUBL East Lansing, MI: Michigan State University. 60 p. Ph.D. thesis.
ABST The western white pine seed sources studied represent a relatively homogeneous population; an overall lack of genetic differentiation in relation to seed source was observed in the physiological, morphological, and biochemical traits chosen for analysis. The terpene differences observed occurred only between widely separated areas and were unrelated to the elevation or latitude of the parent trees. Seed origin did not appear to be an important determinant of photosynthetic efficiency or CO_2 compensation point. At only one of the three light intensities examined was the seed source important in influencing photosynthetic efficiency. No differences among progeny were observed in the compensation point, at three light intensities and two temperatures. Height growth parameters were characterized by a similar homogeneity. There were no distinctions among sources in total height and only slight differences in the form of their growth curves.
KEYW Provenance study, monoterpenes, height growth, photosynthetic efficiency.

76 AUTH Townsend, A. M., Hanover, J. W.
DATE 1972
TITL Altitudinal variation in photosynthesis, growth, and monoterpene composition of western white pine (*Pinus monticola* Dougl.) seedlings.
PUBL Silvae Genetica. 21: 133-139.
ABST Seed from 24 parent trees were sown in altitudinal plots in the fall of 1965. The following seed characteristics were studied: (1) cortical oleoresin monoterpene composition, (2) photosynthesis and respiration, (3) total height and weekly growth throughout the growing season. The main conclusion drawn was that western white pine seed sources studied represented quite variable populations, but the variability appears to have only a slight association with environmental gradients.
KEYW Altitudinal variation, photosynthesis, seedling growth, monoterpenes, oleoresin.

577 AUTH Trappe, J. M.
DATE 1960
TITL Some probable mycorrhizal associations in the Pacific Northwest. II.
PUBL Northwest Science. 34: 113-117.
ABST The following mycorrhizal association is reported for western white pine: *Suillus granulatus*, on the west slope of the Cascade Range in Washington, elevation 2,000 ft.
KEYW Mycorrhiza, *Suillus granulatus*.

578 AUTH Troxell, H. E.
DATE 1954
TITL The use of Rocky Mountain species for pulping.
PUBL Journal of Forestry. 52(8): 583-586.
ABST Many tree species are quite acceptable for the manufacturing of paper and paper products although only small portions of the timber have been used for making pulp. As regional population and the national demand for paper products increase, the region will supply more of the Nation's future needs for pulpwood and paper and paper products by development of local manufacturing plants.
KEYW Utilization, pulpwood, economics.

579 AUTH Turner, J., Singer, M. J.
DATE 1976
TITL Nutrient distribution and cycling in a subalpine coniferous forest ecosystem.
PUBL Journal of Applied Ecology. 13: 295-301.
ABST The study was an attempt to characterize nutrient pools and the magnitude of nutrient transfers in a subalpine forest of old-growth Pacific silver fir (*Abies amabilis*). Standing biomass (44 percent of which were dead) consisted mainly of western white pine, indicating a recent change in species composition. Trees contributed by far the greatest amount of biomass and nutrients.
KEYW Nutrient distribution, nutrient cycling, biomass.

580 AUTH U.S. Department of Agriculture, Forest Service
DATE 1921
TITL Accelerated growth of western white pine after cutting.
PUBL Applied Forestry Note RS-D-1. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Borings were taken on 40 trees ranging in diameter at breast height from 3 to 14 inches. A very distinct acceleration in growth is noticeable as is a relation between height growth recovery and diameter recovery after cutting.

KEYW Cutting, height growth, diameter growth, recovery.

581 AUTH U.S. Department of Agriculture, Forest Service
DATE 1940
TITL Preliminary 1939 log prices in the Northern Rocky Mountain Region.
PUBL Research Note 7. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 2 p.
ABST Preliminary log prices for western white pine in 1939 are listed as total value of $558,838; average price per thousand bd ft of $17.90, and a price range of $10.00-21.75. Quantity was 31,218 thousand bd ft.
KEYW Log prices.

582 AUTH U.S. Department of Agriculture, Forest Service
DATE 1941
TITL Determining tree d.b.h. from stump measurements.
PUBL Research Note 16. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 6 p.
ABST Contains charts showing the relationship between stump size and tree diameter for five species including western white pine.
KEYW Stump size, tree diameter.

583 AUTH U.S. Department of Agriculture, Forest Service
DATE 1941
TITL Preliminary 1940 log prices in the Northern Rocky Mountain Region.
PUBL Research Note 15. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 2 p.
ABST Log prices for western white pine from all Districts averaged $18.05 per thousand bd ft; total value was $1,001,049 and total quantity was 55,465 thousand bd ft log scale.
KEYW Log prices.

584 AUTH U.S. Department of Agriculture, Forest Service
DATE 1949
TITL Pole blight—this is how to recognize it.
PUBL Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 6 p.
ABST A description of pole blight with photos.
KEYW Pole blight.

585 AUTH U.S. Department of Agriculture, Forest Service
DATE 1950
TITL Pathologists use planes to spot pole blight of pines.
PUBL Research Administration Press Release 289-50. Missoula, MT: U.S. Department of Agriculture, Forest Service. 1 p.
ABST Describes the use of planes for the scouting of pole blight areas.
KEYW Pole blight, aerial survey.

586 AUTH Vaartaja, O.
DATE 1960
TITL Photoperiodic response in seedlings of five species of *Betula* and *Pinus*.
PUBL Canadian Journal of Botany. 38: 807-813.
ABST The existence of photoperiodic response was experimentally established in *Betula lenta, B. mandshurica* var. *japonica, B. glandulosa, Pinus lambertiana*, and *P. monticola*. The responses of seedlings from different latitudes and altitudes were in accordance with the theory of photoperiodic ecotypes. Data indicate that the seedlings of *P. monticola* possess a marked photoperiodic response. If it was normal, the interaction of photoperiod and seed source would indicate the existence of photoperiodic ecotypes in *P. monticola*.
KEYW Photoperiod, ecotypes, seed source.

587 AUTH Vandersar, T. J. D.
DATE 1978
TITL Resistance of western white pine to feeding and oviposition by *Pissodes strobi* Peck in western Canada.
PUBL Journal of Chemical Ecology. 4(6): 641-647.
ABST Forced and choice feeding and oviposition experiments were conducted by caging overwintered *Pissodes strobi* on lateral branches or leaders of sympatric Engelmann spruce and/or western white pine trees. Results indicate that the releasing stimulus for feeding is present in the bark of both conifer species and suggest that a separate releasing stimulus for oviposition is absent from western white pine.
KEYW *Pissodes strobi*, weevil.

588 AUTH Vinje, M. G., Worster, H. E.
DATE 1970
TITL Hydrogen sulfide alkaline pulping. III. Effect of major process parameters and response of some North American softwood species.
PUBL Tappi. 53(6): 1082-1086.
ABST The major process parameters in the hydrogen sulfide kraft process are pressure, type

and quantity of alkaline "buffer," reuse of spent liquor, liquor-to-wood ratio, time, and temperature. The pulp yield increase is quite sensitive to small changes in hydrogen sulfide pressure over a certain pressure range. Pulp yield increases of approximately 6 percent based on wood were obtained by the application of (a) 0.5 percent calcium oxide in the form of calcium hydroxide or carbonate and (b) 1.4 percent sodium oxide in the form of sodium carbonate, kraft green liquor, or sodium hydroxide. Recycling spent pretreatment liquor tended to have a slightly beneficial effect on the yield increase. Liquor-to-wood ratios of 4.0/1 to 5.4/1 gave optimum results with both fresh and recycled liquors. Hydrogen sulfide-treated Douglas-fir, western redcedar, and western white pine chips, and a southern pine chip mixture required slightly less active alkali based on wood in kraft pulping than the corresponding untreated chips. Screened pulp yield increases of 5.3-6.6 percent on wood compared to the draft process were obtained with the wood species examined. The hydrogen sulfide kraft pulps were bleached to the same high brightness by the CEHDED sequence as the conventional kraft pulps and the yield increases were retained regardless of wood species.

KEYW Pulping, alkaline pulping, sulfate pulping, hydrogen sulfide, high-yield pulping, calcium compounds, sodium compounds, pressure, buffers, spent liquors, liquor-wood ratio, bleaching.

9 AUTH Vité, J. P., Rudinsky, J. A.
DATE 1959
TITL The water conducting systems in conifers and their importance to the distribution of trunk injected chemicals.
PUBL Contributions of the Boyce Thompson Institute. 20: 27-28.
ABST The routes by which water is conducted upward in conifers have been studied by injecting acid fuchsin near the base of young to middle-aged trees belonging to 23 species from 12 genera and four families. Five different patterns of translocation were detected in the sapwood of the conifers examined. Type A, the spiral ascent turning right, is characteristic of the investigated species of *Abies, Larix, Picea,* and subgenus *diploxylon* of the genus *Pinus.* The spiral runs from the outermost growth ring clockwise toward the center of the stem. Type B, the spiral ascent turning left, possessed by *Pinus monticola* and *P. lambertiana,* shows the same system as Type A, but in a reversed direction.
KEYW Water-conducting system, translocation.

590 AUTH Voldert, E.
DATE 1956
TITL Holzeigenschaften von gastbaumarten.
PUBL Holz Alsroh- und Werkstoff. 14: 81-86.
ABST Compares growth of several conifer species, including western white pine.
KEYW Growth rate.

591 AUTH Wahlenberg, W. G.
DATE 1924
TITL Circumventing delayed germination in the nursery.
PUBL Journal of Forestry. 22: 574-575.
ABST Delayed germination is common in western white pine. Fall sowing results in prompt and complete germination the following spring. This results in an even-aged stand and makes shading and mulching unnecessary.
KEYW Seed germination, nursery, delayed germination.

592 AUTH Wahlenberg, W. G.
DATE 1924
TITL Fall sowing and delayed germination of western white pine seed.
PUBL Agricultural Research. 28: 1127-1131.
ABST Experiments in northern Idaho and western Montana show that fall sowing of western white pine seed results in prompt and complete germination the following spring. Fall sowing eliminates the hold-over germination which follows spring sowing, thus assuring the production of a regular, even-aged seedling crop. The correct time for sowing within the fall season is very important. The findings in this report may not apply directly elsewhere, since climate and soil combine to make the sowing problem essentially local.
KEYW Seed dormancy, seed germination, percent germination sowing date, fall sowing.

593 AUTH Wahlenberg, W. G.
DATE 1924
TITL Overcoming delayed germination in the nursery.
PUBL Applied Forestry Note 53. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 2 p.
ABST Intensive experiments in fall sowing of western white pine seed were initiated to alleviate delayed germination. Final results showed that prompt and complete germination was secured the spring following fall sowing. In one case fall-sown plots had effected 83 percent of their total germination before the end of May, while less than 14 percent of the

germination of spring-sown plots had been effected at that time. Fall sowing of western white pine seed in the nursery is strongly advocated.

KEYW Fall sowing, spring sowing, delayed germination, nursery.

594 AUTH Wahlenberg, W. G.
DATE 1924
TITL The results of sowing in the Northern Rocky Mountain Region.
PUBL Applied Forestry Note 43. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Chronicles the failure of direct seeding by broadcast or corn planter in the Northern Rocky Mountains after the 1910 fires. Later attempts were made to sow all important species, including western white pine, by using seed spots. Survival was less than 15 percent for all species except Douglas-fir, which had not more than 20 percent survival. Failures are attributed to rodents, drought, cutworms, frost heaving, and mechanical obstacles.
KEYW Direct seeding, seed spots.

595 AUTH Wahlenberg, W. G.
DATE 1925
TITL Forestation research in Montana and north Idaho.
PUBL Journal of Forestry. 23: 589-599.
ABST A general discussion of current (1925) practices in District 1 of the Forest Service. The following information is given for western white pine: seedbed density was not to exceed 8,000 or 9,000 per 48-ft^2 bed. All white pine seed was being sown in early September. About 5/8 inch of sand or sand and soil was being used for seed cover. Roots were pruned to a depth of 4-5 inches. The cone method was the best planting method for western white pine.
KEYW Seedbed density, sowing time, root pruning.

596 AUTH Wahlenberg, W. G.
DATE 1925
TITL Reforestation by seed sowing in the Northern Rocky Mountains.
PUBL Agricultural Research. 30: 637-641.
ABST Of all the early direct-seeding projects in the Northern Rocky Mountain Region, only 6 percent were successful or partially successful. Later intensive experiments with seeding in prepared spots also failed to indicate practicable methods of direct seeding for this region. Speaking in terms of the percentage of spots with one or more survivors, about 20 percent survival was obtained with Douglas-fir under the best conditions, whereas other species were below 15 percent in survival in all cases. Western white and western yellow pine and Engelmann spruce, important commercial timber trees of the region, are essential in reforestation and are included in the group of species making an extremely poor showing in the experiments.
KEYW Reforestation, direct seeding.

597 AUTH Wahlenberg, W. G.
DATE 1926
TITL Age classes of western white pine planting stock in relation to aspect of planting site in northern Idaho.
PUBL Agricultural Research. 33: 611-619.
ABST In general the survival of planted western white pine trees places 2-2 transplanted stock at the top, with 1-2, 2-1, 2-0, and 1-1 following in descending order. Height growth also conforms to this order. The cost of survival definitely favors 2-0 seedlings on moderate sites, and 2-2 or 1-2 only on the more severe sites. Aspect of planting site is as important as the class of stock. Of the four exposures tested, the lowest survival accompanied by the fastest growth occurred on the west exposure. The east, northeast, and northwest aspects showed considerably higher survival in the order given.
KEYW Mortality season, planting stock, growth rate.

598 AUTH Wallis, G. W.
DATE 1976
TITL Growth characteristics of *Phellinus* (*Poria*) *weirii* in soil and on root and other surfaces.
PUBL Canadian Journal of Forest Research. 6(2): 229-232.
ABST Growth of *Phellinus* (*Poria*) *weirii* from alder block inoculum into the surrounding soil to infect healthy roots was less than 10 cm. Tree-to-tree spread of this root rot fungus, beyond that which would occur as a result of root contact, may be facilitated by growth of the mycelium over roots of minor vegetation and over wood buried in soil.
KEYW *Phellinus* (*Poria*) *weirii*, root inhabiting fungus, ectotrophic mycelial growth, bridging, root contact.

599 AUTH Walrath, F. J.
DATE 1927
TITL The better utilization of western white pine match stock.
PUBL Idaho Forester. 9: 19-20, 38.
ABST Identifies three ways to prevent blue stain: air seasoning, kiln drying, and treating with an antiseptic solution. Kiln drying at 140 °F for 6 hours was the only effective preventive treatment identified in a survey of 13 match

companies. Bleaching stained wood with chlorine may be feasible. Some companies are beginning to use blued material for match stock.
KEYW Match stock, utilization, blue stain, fungi, kiln drying.

600 AUTH Walsh, S. J.
DATE 1980
TITL Coniferous tree species mapping using Landsat data.
PUBL Remote Sensing of Environment. 9: 11-26.
ABST The identification and mapping of 12 surface-cover types within Crater Lake National Park, OR, including seven classes of coniferous tree species, has been accomplished through the use of Landsat digital data. The 12 surface-cover types were mapped with an average accuracy of 88.8 percent as compared with detailed ground truth.
KEYW Landsat, mapping cover types.

601 AUTH Walters, J.
DATE 1953
TITL Pitch moth infestation in western white pine.
PUBL Canadian Department of Agriculture, Science Service, Bi-monthly Progress Report. 9(1): 3-4.
ABST During November 1952, personnel of the Laboratory of Forest Biology, Vernon, visited a timber sale at Magna Bay, Shuswap Lake, to determine if insects were a factor in the unhealthy condition of western white pine (*Pinus monticola*) on the area. The inspections revealed that two species of pitch moths, tentatively identified as *Dioryctria zimmermani* and *Vespamima novaroensis*, were present in epidemic proportions. It was estimated that about 50 percent of the stand of white pine over 6 inches d.b.h. were infested in varying degrees. The infestation extended beyond the area of the timber sale (2,000 acres). In most cases the pitch moth attacks were associated with blister rust cankers. Apparently, the pitch moth population built up on diseased trees to its present status where it attacks healthy trees.
KEYW Pitch moth, *Dioryctria zimmermani*, *Vespamima novaroensis*, disease-insect relationships, blister rust.

602 AUTH Walters, J., Soos, J.
DATE 1962
TITL The vertical and horizontal organization of growth in some conifers of British Columbia.
PUBL Faculty Forest Research Paper 51. Vancouver, BC, Canada: University of British Columbia. 11 p.
ABST Studies were made to test the validity of earlier findings on Douglas-fir, western hemlock, western redcedar, western white pine, and Pacific silver fir. Thirty-nine trees ranging in age from 10 to 71 years and in height from 8 to 110 ft were analyzed. Trees were sectioned at the midpoint of each internode and the width of each annual ring was measured. Data from 19 trees are presented. The vertical and horizontal organization for the five species is described in terms of three sequences of ring width measurements. The sequences are shown to parallel those recognized earlier for red pine. Maximum mean cambial circumference and the most recent first order sequence of cambial circumference are shown to vary according to crown classification and site quality. The possible application of these relationships is discussed briefly with reference to site evaluation.
KEYW Vertical growth, horizontal growth, morphogenesis, ring width, growth organization.

603 AUTH Walters, J., Soos, J.
DATE 1963
TITL Shoot growth patterns of some British Columbia conifers.
PUBL Forest Science. 9: 73-85.
ABST The seasonal distribution of terminal and lateral shoot growth of *Pseudotsuga menziesii, Tsuga heterophylla, Thuja plicata*, and *Pinus monticola* was studied. Measurements were recorded weekly during the growing seasons of 1960 and 1961 on trees from 6 to 24 years old and from 2 to 22 ft high. Study areas were located at elevations of 550 and 1,500 feet. Results are presented graphically. The main conclusions are: (1) the phenology of shoot growth was not related to monthly precipitation or to mean monthly maximum and minimum temperatures, (2) the rate of growth and dates of annual commencement and termination of growth of individual trees were highly variable phenomena, (3) the general form of growth curves was similar from year to year indicating the influence of strong hereditary control, (4) the quantity of leader growth and length of growing period were not correlated, and (5) the relative rate of cumulative percentage growth of *Pinus monticola, Pseudotsuga menziesii, Tsuga heterophylla*, and *Thuja plicata* was in the order listed.
KEYW Shoot growth pattern, leader growth.

604 AUTH Warren, L. E.
DATE 1980
TITL Control of brush on conifer plantations with triclopyr ester.
PUBL In: Proceedings, Western Society of Weed Science. 35: 38-45.

ABST This report presents results of research to establish efficacious rates of triclopyr, carriers, and additives for effective brush control during the tolerant growth stages of conifers.
KEYW Brush control, herbicide treatments, triclopyr, conifer release, phenological stage.

605 AUTH Watson, C. W.
DATE 1925
TITL Young stands of western white pine progress report.
PUBL Idaho Forester. 7:21.
ABST Growth and yield of reproduction is sampled and a prediction is listed to 1984.
KEYW Reproduction, predicted yield.

606 AUTH Watson, C. W.
DATE 1927
TITL Partial cutting and stimulated growth in western white pine.
PUBL Idaho Forester. 9: 14-16, 42-44.
ABST Growth conditions for the white pine type were excellent in the region in which the Clearwater Timber Company was operating. An examination of their lands showed that a large part was covered with timber of the 80- to 100-year age class. Intensive studies covering four sections of this timber showed that the average acre contained a total volume of 37,603 bd ft, taking the trees down to 7 inches d.b.h. If a diameter limit of 11 inches is adopted for cutting, the volume removed would amount to 35,464 bd ft. Allowing for losses in logging the original stand, in a period of 35 years the residual material should produce a crop of about 8,212 bd ft, of which 75 percent would be white pine. To test these conclusions a series of eight 1-acre sample plots were laid out. These were logged, and periodic measurements on them were expected to solve the problem of growth in residual stands in this particular region.
KEYW Partial cutting, residual stands.

607 AUTH Watt, R. F.
DATE 1950
TITL Approach toward normal stocking in western white pine stands.
PUBL Northwest Science. 24: 149-157.
ABST The study is based upon growth records for 54 permanent yield plots established in 1925 and 1926 in northern Idaho while collecting data for second-growth western white pine yield tables. Tentative conclusions are: (1) understocked and overstocked stands tend to approach an average stocking near the values given in the second-growth western white pine yield tables for fully stocked stands. (2) The effect of age of stand on rate of approach to normal stocking appears to be slight. (3) The rate of change in mortality varies significantly with departure from near-normality density. (4) Individual plots showed much variation from average trends; therefore, it is unlikely that growth on small areas for short periods can be predicted with much precision. Predictions for larger areas and longer periods will be relatively reliable.
KEYW Normal stocking, natural reproduction, permanent yield plots, understocking, overstocking.

608 AUTH Watt, R. F.
DATE 1950
TITL Growth in understocked and overstocked western white pine stands.
PUBL Research Note 78. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The study showed that, over a period of time, understocked and overstocked western white pine stands tend to approach certain central values. However, these values are not exactly the values given in the western white pine yield tables (by Haig). For example, basal area stocking tends to approach 92 percent of the yield table volume. Scribner board-foot volume seems to be approaching 88 percent of normal volume and total cubic-foot volume 98 percent of normal. These percentages indicate that the white pine yield table values may be somewhat too high.
KEYW Growth stand density.

609 AUTH Watt, R. F.
DATE 1951
TITL Snow damage in a pole stand of western white pine.
PUBL Research Note 92. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Observations on a 2-acre permanent sample plot located in a severely damaged stand in Deception Creek Experimental Forest, ID, revealed the extent and nature of snow damage. The most important result of the winter's damage was a reduction of volume and growing stock on the area. On the study plot, 30 percent of the cubic volume, 37 percent of the trees, and 32 percent of the basal area were lost. Unusually heavy losses of the kind described are due to a combination of climatic conditions including wet snow, freezing temperatures, and wind.
KEYW Snow damage.

610 AUTH Watt, R. F.
DATE 1952
TITL Western white pine stands show irregular growth pattern.
PUBL Research Note 113. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 1 p.
ABST Twenty-five-year records of seven sample plots established in 1925 in the Oro Grande Creek drainage, Clearwater National Forest, illustrate irregular growth rates. The plots have a site index of 65, total 3.23 acres, and were 103 years old at the time of establishment. The stands grew an average of 490 bd ft per acre per year during the 25-year period, growing from 71,956 bd ft per acre to 84,200. Haig's yield tables would have forecast a growth of 667 bd ft per acre per year during the 25-year period.
KEYW Growth pattern stand.

611 AUTH Watt, R. F.
DATE 1953
TITL Site index changes in western white pine forests.
PUBL Research Note 132. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 2 p.
ABST Only small changes in site index have occurred on 88 permanent sample plots in the western white pine type. As shown by the magnitude of standard deviations, the plot data exhibited considerable variation. Some of this variation may have resulted from erratic changes in site index caused by methods of measurement used by the many different field parties over a period of 25 years. However, the changes in site index cannot be charged in very great part to errors in field work, nor can they be explained by recorded changes in soil and climate. Slight errors in the curves used for determining site index are the most logical explanation. In any event, the changes in site index are so small that site index values currently in use are sufficiently accurate for application to second-growth western white pine stands.
KEYW Site index.

612 AUTH Watt, R. F.
DATE 1954
TITL Mortality in second-growth stands of the western white pine type.
PUBL Research Note INT-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 5 p.
ABST A study of mortality records collected on 38 permanent sample plots showed mortality to be extremely variable. However, mortality increased with volume and age of the stand, and in the case of board-foot mortality, with site index. At 100 years of age, 10 percent of the total board-foot production, 22 percent of the cubic-foot volume, and 30 percent of the basal-area production had been lost through mortality. Wind and snow caused nearly half of this mortality; suppression, insects, and diseases were other important causes of death. One-fifth of the cubic-foot mortality was in trees less than 4.6 inches d.b.h., material considered to be unmerchantable. Two-thirds of the total board-foot mortality was in trees now of merchantable size, 10.6 inches d.b.h. and larger. However, because of the small volumes per acre available for salvage annually, much of the mortality probably will never have economic value. Natural mortality provides very crude but inexpensive thinning of second-growth stands.
KEYW Mortality, second-growth stands, gross production, wind, snow, insects, disease.

613 AUTH Watt, R. F.
DATE 1960
TITL Second-growth western white pine stands.
PUBL Technical Bulletin 1226. Washington, DC: U.S. Department of Agriculture, Forest Service. 60 p.
ABST Several analyses of data gathered on 94 permanent plots in second-growth western white pine stands from 20 to 100 years old were made. The plots were remeasured periodically to give information for 340 5-year growth periods. Repeated site index determinations were analyzed to see if site index changed with time, and, if so, what factors influenced the rate of change. It was determined that a statistically valid trend in site index occurred, but that the changes in site index were too small to have practical significance. Analysis of species composition changes showed that the composition of western white pine stands is established by the time the stands reach 30 years of age, and that changes in composition up to the age of 100 years are small. About half of the total mortality was attributed to wind and snow damage. Other important causes of mortality were insects, diseases, and suppression. Mortality caused the loss of 30 percent of the basal area, 22 percent of the cubic-foot volume, and 10 percent of the board-foot volume produced as the stands grew from age 30 to 100 years. The volume of mortality in a stand during a 5-year period was found to be correlated with the age and volume of the stands. Of these two variables, stand volume was the more important.

KEYW Second growth, mortality.

614 AUTH Weidman, R. H.
DATE 1922
TITL Intensive management on a demonstration forest.
PUBL Applied Forestry Note 35. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Gives background on establishment of Priest River Experimental Forest and stresses its use as a demonstration forest of intensive management of western white pine.
KEYW Intensive management, demonstration forest, Priest River Experimental Forest.

615 AUTH Weidman, R. H.
DATE 1924
TITL Preliminary results of the western white pine.
PUBL District 1 Applied Forestry Note 49. Missoula, MT: U.S. Department of Agriculture, Forest Service. 3 p.
ABST Contains a preliminary normal yield table for western white pine in Idaho, by age class on three types of sites. Curves of mean and current annual volume growth per acre based on plots in this study show that the greatest current growth in board feet is made at about 70 years and that the mean annual growth culminates at about 100 years.
KEYW Age class, mean annual growth, yield.

616 AUTH Weidman, R. H.
DATE 1927
TITL Prolific seed production in the forests of northern Idaho.
PUBL Northwest Science. 1: 79-80.
ABST In a moderately good seed year mature white pine stands produced 75,000 to 150,000 germinable seeds per acre. This study suggests that more prolific seedbearers such as cedar and hemlock would produce three or four times as much as white pine.
KEYW Seed production.

617 AUTH Weidman, R. H.
DATE 1933
TITL Progress of research in silviculture in the Inland Empire.
PUBL Northwest Science. 7: 67-71.
ABST Gives an overview of current progress of research in silviculture in the Inland Empire, including western white pine.
KEYW Silviculture.

618 AUTH Weir, J. R.
DATE 1923
TITL The effect of broadcast burning of sale areas on the growth of cull-producing fungi.
PUBL Journal of Forestry. 21: 183-184.
ABST Records brief results of observations in Idaho and Montana on the effect of clean burning on the production of sporophores of cull-producing fungi. The majority of cull fungi fruit with difficulty in the open exposed condition of a clean-cut area.
KEYW *Poria subacida, Polyporus schweinitzii, Fomes pini, Fomes annosus, Armillaria mellea,* cull fungi.

619 AUTH Weir, J. R., Hubert, H. H.
DATE 1919
TITL A study of the rots of western white pine.
PUBL Bulletin 799. Washington, DC: U.S. Department of Agriculture. 24 p.
ABST Within the area covered by British Columbia, Oregon, Washington, Idaho, and Montana, the three main wood-destroying fungi of western white pine (in order of importance) are *Trametes pini, Polyporus schweinitzii,* and *Fomes annosus.* Data show age as a prominent factor in determining the amount and stage of decay in a stand as well as the number of sporophore-bearing trees. Site also influences the rot in a stand. Proper pathological marking rules and practical methods for the disposal of infected slash are recommended as methods for control.
KEYW Volume losses, wood rot, *Trametes pini, Polyporus schweinitzii, Fomes annosus.*

620 AUTH Welch, D. S.
DATE 1947
TITL Study of the mortality of young western white pine trees.
PUBL Unpublished report, Special Research Project 11. Spokane, WA: U.S. Department of Agriculture, Bureau Plant of Industry, Office of Forest Pathology. 17 p. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID.
ABST The pole blight disease of *Pinus monticola* was studied in northern Idaho in 1947. Diseased trees were studied on the Coeur d'Alene, Kaniksu, and St. Joe National Forests. Intensive study of all the trees on a 0.1-acre sample plot, supplemented by field observation, served as a basis for a symptom description. The relation of age of trunk lesions to time of growth reduction was studied in the sample plot. In 13 of 19 cases, the trunk lesions antedated checking of growth of either terminals or wood rings. The possible causes of the disease are listed.
KEYW Pole blight.

621 AUTH Wellner, C. A.
DATE 1940
TITL Effects of cleaning in a reproduction stand of western white pine and associates.
PUBL Research Note 4. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Results on three cleaning plots established in 1935 in the upper west branch drainage of Priest River in the Kaniksu National Forest, ID, and remeasured in 1939, give a good example of the possibilities of this type of stand improvement in western white pine. These plots test the freeing of white pine reproduction from competing western larch and lodgepole pine. All tests to date speak well for this type of stand improvement work in the western white pine region. Cleanings are one of the cheapest stand improvement measures, and they appear to be one of the most effective.
KEYW Cleaning stand.

622 AUTH Wellner, C. A.
DATE 1940
TITL Relationships between three measures of stocking in natural reproduction of the western white pine type.
PUBL Journal of Forestry. 38: 636-638.
ABST The common use of more than one measure of stocking in natural reproduction stands has necessitated a means to convert one measure to another in order to compare stocking described in different terms. Three measures of stocking used in reproduction stands of the western white pine type are discussed in this article and a converting method is given, the principle of which is applicable elsewhere.
KEYW Natural reproduction, stocking, stocking measurements.

623 AUTH Wellner, C. A.
DATE 1941
TITL Blister rust control in relation to white pine silviculture.
PUBL Idaho Forester. 23: 13-15.
ABST Silviculture practices that aid in blister rust control must be considered. Blister rust control should not be considered for areas where white pine cannot be economically grown.
KEYW Silviculture in blister rust control.

624 AUTH Wellner, C. A.
DATE 1946
TITL Estimating light intensity in residual stands in advance of cutting.
PUBL Research Note 47. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Gives a "rule of thumb" method for estimating light intensity in mature stands of the western white pine type.
KEYW Light intensity, mature stands.

625 AUTH Wellner, C. A.
DATE 1946
TITL Improving composition in young western white pine stands.
PUBL Research Note 43. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 6 p.
ABST Stand composition and density in western white pine forests can be controlled most effectively, and with the least cost, by cleanings made during the juvenile stage of the stand. To be most effective, cleanings should be delayed until dominance is well established (stand age usually about 10 years), at which time the cleaning operation should be heavy. Not only trees of equal or greater height than white pine but also trees of lesser height, especially of the intolerant species, should be cut. A follow-up cleaning in 3 to 5 years after the first cleaning is desirable to maintain the lead of western white pine. Through cleanings effectively applied, a high proportion of western white pine can be maintained in future stands.
KEYW Cleaning stand, stand improvement.

626 AUTH Wellner, C. A.
DATE 1946
TITL Recent trends in silvicultural practice on National Forests in the western white pine type.
PUBL Journal of Forestry. 44: 942-944.
ABST Silvicultural practices in the western white pine type have been markedly affected by (1) truck logging; (2) greater utilization of species associated with western white pine; (3) the belief that losses from mountain pine beetle can be prevented by partial cuttings; (4) the use of silvicultural practices to aid control of blister rust; and (5) the increasing emphasis on getting all stands under management. Greatest changes are in mature stands.
KEYW Silviculture, truck logging, mountain pine beetle, species utilization.

627 AUTH Wellner, C. A.
DATE 1947
TITL Forest protection in the silviculture of western white pine forests.
PUBL Northwest Science. 21: 109-112.

ABST The author stated that only by a correlation and integration of protection, economics, and silvics can a sound practice of silviculture result. He then discussed various silvicultural methods to aid in control of forest insects, forest diseases, and fire. Cutting practices in immature, mature, and overmature stands to aid in forest protection were outlined.
KEYW Forest protection, silviculture, insect control, disease control, fire control, cutting practices, partial cutting.

628 AUTH Wellner, C. A.
DATE 1947
TITL Marking instructions for the white pine type in the Northern Rocky Mountain Region.
PUBL Unpublished report. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 14 p. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID.
ABST Discusses factors governing silvicultural practices and objectives in the white pine type, and then gives marking instructions for various stand conditions.
KEYW Timber marking, vigor classes, *Ribes* populations.

629 AUTH Wellner, C. A.
DATE 1947
TITL Pole blight: a new disease of western white pine.
PUBL Station Paper 8. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 5 p.
ABST Gives a summary of current knowledge on damage, extent, history, symptoms, impact, and needed research on pole blight.
KEYW Pole blight.

630 AUTH Wellner, C. A.
DATE 1948
TITL Light intensity related to stand density in mature stands of the western white pine type.
PUBL Journal of Forestry. 46: 16-19.
ABST Describes a method developed for estimating light intensity beneath the canopy in western white pine forests. Summation of diameters per acre is recommended as the most suitable measure of stand density to use in obtaining an estimate of light intensity. The relationship of light intensity to stand density is graphically illustrated, and tables show stand density equivalents for given light intensities beneath the canopy in mature stands of the western white pine type.
KEYW Light intensity, stand density, summation of diameters, canopy.

631 AUTH Wellner, C. A.
DATE 1948
TITL New disease threatens western white pine stands.
PUBL Journal of Forestry. 46: 294-295.
ABST Summarizes the extent of pole blight (70,000 acres) and describes the symptoms and history. Emphasizes the lack of knowledge concerning cause(s) for the disease and the need for intensive research concerning the problem.
KEYW Pole blight, pole blight acres.

632 AUTH Wellner, C. A.
DATE 1949
TITL Sale area betterment and stand improvement handbook for Northern Region.
PUBL Unpublished report. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 63 p. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Moscow, ID.
ABST These instructions describe technical specifications and policies for performance of work with sale area betterment as provided for by the Knudson-Vandenberg Act and timber stand improvement operations from any source.
KEYW Stand improvement, silviculture methods, Knudson-Vandenberg Act, white pine type, ponderosa pine type, western larch-Douglas-fir type, lodgepole pine type, Engelmann spruce type, east-side Douglas-fir type.

633 AUTH Wellner, C. A.
DATE 1951
TITL Conservation influences of forest management.
PUBL In: Idaho conservation source book. Moscow, ID: University of Idaho. p. 93-98.
ABST There are many beneficial uses of forest lands. These uses are often complementary, but more often overlap or conflict. True application of conservation must achieve a balance between them. The author discusses the various uses.
KEYW Multiple use, conservation.

634 AUTH Wellner, C. A.
DATE 1952
TITL A vigor classification for mature western white pine trees in the Inland Empire.

PUBL Research Note 110. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The vigor classification for mature western white pine includes the following characteristics: crown class, crown density, live crown length in percent of total tree height, crown width, crown color, tip vigor, and dead branchlets or branches in upper crown.
KEYW Vigor classification, mature trees.

635 AUTH Wellner, C. A.
DATE 1959
TITL What research do we most need and how can we get it?
PUBL Western Forestry and Conservation Association, Proceedings. 1959: 45-49.
ABST A general talk presented at the 50th Western Forest Conference.
KEYW Research needs.

636 AUTH Wellner, C. A.
DATE 1962
TITL Silvics of western white pine.
PUBL Miscellaneous Publication 26. Washington, DC: U.S. Department of Agriculture, Forest Service. 24 p.
ABST Gives a detailed description of the silvics of western white pine.
KEYW Silvics, silviculture, habitat type, life history, racial variation, seeding habits, vegetative propagation, seed germination, seedling development, leaf litter nutrient content.

637 AUTH Wellner, C. A.
DATE 1964
TITL The impact of multiple use on silviculture in the Northern Rocky Mountain and Intermountain Regions.
PUBL Society of American Foresters, Proceedings. 1964: 20-22.
ABST It is not the impact of multiple use itself on silviculture that is of concern, but rather the effect of one use on another. Silviculture is simply the cultural means to accomplish the objectives of management once the use or uses of land have been determined.
KEYW Multiple use, silviculture.

638 AUTH Wellner, C. A.
DATE 1965
TITL Silvics of western white pine.
PUBL In: Silvics of forest trees of the United States. Agriculture Handbook 271. Washington, DC: U.S. Department of Agriculture, Forest Service. p. 477-478.
ABST A general description of the silvicultural characteristics of western white pine.
KEYW Habitat type, climate, range, soils, topography, life history, reproduction, early growth, saplings, dominant, codominant, mean annual increment, races, hybrids, maturity.

639 AUTH Wellner, C. A.
DATE 1967
TITL A silviculturist looks at the future of forest disease control.
PUBL Fifteenth Western International Forest Disease Work Conference Proceedings. 1967: 44-48.
ABST The author argues two major points: (1) Use what we know. (2) Develop imaginative new methods for recognition, inventory, evaluation, and control of forest diseases.
KEYW Forest disease control.

640 AUTH Wellner, C. A.
DATE 1969
TITL Progress in the development and maintenance of representative natural coniferous forest ecosystems in the Northern Rocky Mountains.
PUBL In: Coniferous forests of the Northern Rocky Mountains: Proceedings. Missoula, MT: University of Montana, Center for Natural Resources. p. 132-150.
ABST Discusses the need, opportunities and potential for natural areas throughout the Northern Rockies.
KEYW Natural areas, research natural areas, habitat types, cover types.

641 AUTH Wellner, C. A.
DATE 1970
TITL Fire history in the Northern Rocky Mountains.
PUBL Intermountain Fire Research Council Proceedings. 1970: 42-64.
ABST Historically, fires have repeatedly burned nearly every square foot of Northern Rocky Mountain forests. Relative fire resistance of conifers is listed including various characteristics of the species. Number of fires and acres burned from 1908 to 1969 are tabulated.
KEYW Fire history, commercial forests, fire resistance, fire damage by ecosystem, ecosystem acres.

642 AUTH Wellner, C. A.
DATE 1971
TITL The scientific basis for silvicultural practices in forests of the Northern Rocky Mountains.
PUBL Hearing Before the Subcommittee on Public Lands of the Senate, Ninety-Second Congress, First Session on Management Practices on the Public Lands, May 7 and

June 29, Part 3. Washington, DC: U.S. Government Printing Office. p. 929-930.
ABST Silvicultural practices for the regeneration and culture of Northern Rocky Mountain forests must be varied by cover types and by ecological variations within these types.
KEYW Congressional hearings, silvicultural practices.

643 AUTH Wellner, C. A.
DATE 1972
TITL Wildlife and wildlife habitat in ecosystem research.
PUBL Fifty-second annual conference of the Western Association of State Game Commissioners: Proceedings; Portland, OR. p. 452-465.
ABST Management of wildlands requires information about the resources and physical conditions of the land and relevant biological, economic, social, and political knowledge. Research and development by major ecosystems appear to be a promising way to acquire the needed information.
KEYW Cedar-hemlock ecosystem, wildlands, ecosystems research.

644 AUTH Wellner, C. A.
DATE 1976
TITL Frontiers of forestry research—Priest River Experimental Forest 1911-1976.
PUBL Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 148 p.
ABST The establishment, research, and people who have been involved with the Experimental Forest from 1911 to 1976 are included.
KEYW Priest River Experimental Forest.

645 AUTH Wellner, C. A.
DATE 1979
TITL Estimating light intensity beneath coniferous forest canopies: simple field method.
PUBL Research Note INT-250. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST Intensity of light under canopies of coniferous forest can be estimated easily without instruments but with accuracy adequate for numerous administrative and research studies.
KEYW Light intensity, estimations, coniferous forests, forest canopies.

646 AUTH Wellner, C. A., Boyd, R. J., Jr.
DATE 1959
TITL Partial cuttings in mature stands of the western white pine type.
PUBL Society of American Foresters, Proceedings. 1959: 27-32.
ABST Gross growth, mortality, net growth, and diameter growth were strongly associated with tree vigor. Partial cutting on a tree vigor basis has a real place in the management of mature and overmature western white pine stands.
KEYW Partial cuttings, vigor classification, old growth, mature stands.

647 AUTH Wellner, C. A., Foiles, M. W.
DATE 1951
TITL What to see and where to find it on the Deception Creek Experimental Forest.
PUBL Miscellaneous Publication 2. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 76 p.
ABST This booklet gives information on purposes, methods, and results of each of the main experiments located on this forest.
KEYW Deception Creek, mature timber, stand improvement, artificial regeneration, pole blight.

648 AUTH Wellner, C. A., Johnson, F. D.
DATE 1974
TITL Research natural area needs in Idaho, a first estimate.
PUBL Special Report. Moscow, ID: University of Idaho, College of Forestry, Wildlife, and Range Sciences. 179 p.
ABST A report of a workshop on research natural areas for Idaho. A list of needs, potential areas, and proposed areas. Includes discussions on rare and endangered animals and plants in Idaho.
KEYW Natural areas, research natural areas, disjunct plants, endangered animals, Idaho.

649 AUTH Wellner, C. A., Watt, R. F., Helmers, A. E.
DATE 1951
TITL What to see and where to find it on the Priest River Experimental Forest.
PUBL Miscellaneous Publication 3. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 86 p.
ABST Gives a summary of research on the forest. Some of the study plots were established as early as 1911.
KEYW Priest River Experimental Forest, fire research, weather tower, watershed research, silviculture, white pine regeneration, exotic trees, thinning studies, pruning studies, pole blight, blister rust.

650 AUTH Westfall, R. D.
DATE 1972

TITL Development and genetic variation in the cortical terpenes of species of *Pinus* and *Picea*.
PUBL Dissertation Abstracts International. 33B: 1877.
ABST Correlations among cortical monoterpenes in six forest tree species were compared for all species. Other comparisons including within-tree variation were made on some species (not including western white pine). For all species, positive correlations were found between alpha-pinene and camphene, and between 3-carene, gamma-terpinene, and terpinolene. Negative correlations were found between alpha-pinene and 3-carene, alpha-pinene and terpinolene, beta-pinene and 3-carene, and beta-pinene and terpinolene.
KEYW Developmental variation, genetic variation, cortical terpenes.

651 AUTH Wheaton, R. G.
DATE 1924
TITL The stimulation in growth of western white pine remaining on areas after logging.
PUBL Idaho Forester. 6: 37-39.
ABST Discusses stimulation of growth by tree diameter, the amount of release, and crown class.
KEYW Growth stimulation, thinning, rotation length.

652 AUTH Whitford, H. N.
DATE 1905
TITL The forests of the Flathead Valley, Montana. Contributions from the Hull Botanical Laboratory.
PUBL Botanical Gazette. 39: 99-122, 194-218, 276-296.
ABST The physiography, geology, climate, temperature, rainfall, wind, and sunshine of the region are described. Ecological units such as the meadow formation, spruce formation, western larch—Douglas-fir formation, and Douglas-fir—bull pine formation are described. The author also discusses the influence of fire on the forests of the region.
KEYW Ecological units, regional environmental factors, influence of fire.

653 AUTH Whitney, C. N.
DATE 1918
TITL A most remarkable story of pine lumber.
PUBL West Coast Lumberman. 33(395): 73-77.
ABST Describes the white pine resource, supply, annual cut, markets, uses, mechanical and physical properties, and manufacturing.
KEYW Timber volume marketing, utilization, mechanical properties, physical properties, manufacturing, annual cut.

654 AUTH Whitney, C. N.
DATE 1938
TITL Production of lumber and timber products in Idaho and Montana, 1937.
PUBL Applied Forestry Note 86. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 4 p.
ABST Western white pine lumber cut in 1937 was: Idaho, 459,531 thousand bd ft; Montana, 20,186 thousand bd ft; total 479,717 thousand bd ft, or 42.4 percent of total cut.
KEYW Lumber production, percent cut.

655 AUTH Whitney, C. N.
DATE 1939
TITL Production of lumber, lath, and shingles in Idaho and Montana, 1938.
PUBL Applied Forestry Note 91. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The following figures are given for Idaho white pine: lumber cut in 1928—Idaho, 286,754 thousand bd ft; Montana 21,139 thousand bd ft; total 307,893 thousand bd ft or 38.9, percent of the total. Percentage of white pine cut dropped from 50.8 percent in 1933 to 38.9 percent in 1938.
KEYW Lumber, production, percent cut.

656 AUTH Whitney, C. N.
DATE 1940
TITL Production of lumber and timber products in Idaho and Montana, 1939.
PUBL Research Note 8. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST The following statistics are given for western (Idaho) white pine: Idaho, 365,540 thousand bd ft; Montana, 29,989 thousand bd ft; total 395,529 thousand bd ft, or 41.8 percent of lumber cut in the Northern Rocky Mountains, in the year 1939.
KEYW Production.

657 AUTH Whitney, C. N.
DATE 1941
TITL Production of lumber, lath, and shingles in Idaho and Montana, 1940.
PUBL Research Note 14. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Statistics for western white pine are: lumber cut—Idaho, 421,698 thousand bd ft; Montana, 26,962 thousand bd ft; total 448,660 thousand bd ft, or 40.8 percent of total lumber cut in Northern Rocky Mountains.
KEYW Production lumber.

658 AUTH Wicker, E. F., Leaphart, C. D.
DATE 1961
TITL Effects of three antibiotics on tree diseases and forest vegetation following aerial application to western white pine stands.
PUBL Plant Disease Reporter. 45: 722-724.
ABST First-year observations indicated that the antifungal antibiotics cycloheximide (acti-dione) and phytoactin, as used, promoted control only on *Cronartium ribicola*. However, the semicarbazone derivative of cycloheximide appeared to effect some control of *Rhabdocline pseudotsugae*. Phytotoxic responses of forest vegetation other than western white pine were minor for all treatments.
KEYW Antibiotics, cycloheximide, acti-dione, phytoactin, *Rhabdocline pseudotsugae*, phytotoxic reaction.

659 AUTH Wikstrom, J. H.
DATE 1954
TITL 1952 log production for lumber and veneer.
PUBL Research Note 136. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 3 p.
ABST Total log receipts for western white pine in the Northern Rocky Mountain region during 1952 were: 268,491 thousand bd ft, or 13 percent of the total.
KEYW Production logs.

660 AUTH Wikstrom, J. H., Alley, J. R.
DATE 1968
TITL Ranking treatment opportunities in existing timber stands on white pine land in the Northern Region.
PUBL Research Paper INT-46. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 75 p.
ABST Economic evaluation of alternative ways of treating timber stands to increase timber production is a basic step toward efficient use of timber growing funds. The considerations in such an evaluation are discussed in relation to management of white pine land, and sample problems are presented. An EDP investment analysis program containing options usable in ranking stand replacement and timber stand improvement priorities is given, along with instructions for use.
KEYW Diameter growth, thinning, volume, site index, merchantable, cost estimate, value estimate, time period estimate.

661 AUTH Wikstrom, J. H., Wellner, C. A.
DATE 1961
TITL The opportunity to thin and prune in the Northern Rocky Mountain and Intermountain Regions.
PUBL Research Paper INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.
ABST If thinning is started early in the life of the stand, the ratio of cost to revenues will be the greatest. There should be some opportunity for profit in intermediate cuts. Thinning in overcrowded stands would return less.
KEYW Thinning, pruning, stand stagnation, harvest values.

662 AUTH Wilkinson, R. C.
DATE 1981
TITL White pine weevil attack susceptibility of western white pine in the Northeast.
PUBL Research Paper NE-483. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 3 p.
ABST Heights were measured and white-pine weevil attacks were recorded on 668 western white pines interplanted among 109 eastern white pines in a 10-year-old plantation in southern Maine. Less than 13 percent of the western white pines were successfully attacked (leader-killed) by the weevil.
KEYW Height growth, white-pine weevil.

663 AUTH Williams, C. B., Jr.
DATE 1966
TITL Snow damage to coniferous seedlings and saplings.
PUBL Research Note PNW-40. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 10 p.
ABST Western white pine received the following damage ratings in the spring of 1964: none, 18.2 percent; very light, 54.5 percent; light, 18.2 percent; moderate, 9.1 percent; severe, none.
KEYW Snow damage, saplings.

664 AUTH Williams, C. B., Jr.
DATE 1968
TITL Juvenile height growth of four upper-slope conifers in the Washington and northern Oregon Cascade Range.
PUBL Research Paper PNW-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.
ABST The following figures are given for 54 western white pine in this study: average age - 12.0 years, average years to reach breast height - 7.3 years, average internode, 1957-63 - 1.21 feet, average height - 10.4 feet, average d.b.h. - 1.7 inches.

KEYW Juvenile height growth, upper slope, Oregon Cascade Range, internode length, diameter breast height, breast height

665 AUTH Williamson, D. L., Schenk, J. A., Barr, W. F.
DATE 1966
TITL The biology of *Conophthorus monticolae* in northern Idaho.
PUBL Forest Science. 12: 234-240.
ABST Collections of *Pinus monticola* cones were made at 32 collection sites throughout northern Idaho. Longitudinal sections of the majority of these cones were examined and recorded as beetle infested or noninfested and the remaining cones placed in rearing. Life history data were obtained from infested cones collected periodically. *Conophthorus monticolae* was present in all stands sampled. Oviposition occurred from late May to late June, and eggs hatched in 5 to 10 days. Larvae passed through two instars in about 4 weeks and were most abundant from mid-June to mid-July. Pupation occurred within the cones, and transformation to the mature adult required 3 weeks. Overwintering took place in aborted cones. Larvae of *Dioryctria abietella* and *Eucosma rescissoriana* also were abundant. An average of 9 percent (0 to 36 percent) of the cones were infested by *C. monticolae,* and 26 percent (2 to 53 percent) by the cone moths. Seven parasite species also were recovered.
KEYW *Conophthorus monticolae*, cone insects, *Dioryctria abietella, Eucosma rescissoriana,* seasonal history.

666 AUTH Wilse, E.
DATE 1957
TITL Western white pine.
PUBL Skogeieren. 44: 418c.
ABST A description of western white pine.
KEYW Description.

667 AUTH Wilson, A. K.
DATE 1958
TITL Log production in Idaho and Montana, 1956.
PUBL Research Note 54. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p.
ABST Figures for white pines (mostly western white, small amounts of whitebark or limber pine) are 267,443 thousand bd ft in northern Idaho, or 17.3 percent of the total for northern Idaho.
KEYW Log production.

668 AUTH Wilson, A. K.
DATE 1958
TITL Pulpwood production in Idaho and Montana, 1956.
PUBL Research Note 55. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 3 p.
ABST White pines are grouped with ponderosa pine in this tabulation. Together they made up 8.6 percent of the total pulpwood production in Montana and Idaho in 1956.
KEYW Pulpwood production.

669 AUTH Wilson, A. K.
DATE 1964
TITL Output of timber products in Idaho.
PUBL Research Paper INT-13. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 10 p.
ABST Western white pine accounted for 15 percent of the total timber products output in 1962. In northern Idaho the percentage of sawlogs was 20.8 (a total of 241,757 thousand bd ft).
KEYW Timber products, sawlog production, pulpwood production, pole production, veneer log production.

670 AUTH Wise, L. E., Rittenhouse, R. C.
DATE 1949
TITL The presence of arabinose units in pinewood and in kraft pulp.
PUBL Tappi. 32(9): 397-398.
ABST Arabinose, in small amounts, has been found in the hydrolyzates of the following pines: sugar pine, western white pine, and Virginia pine. Thus, it is impossible to differentiate between the "five-needle" and the "two-needle" pines on the basis of their arabinose content. Arabinose was found in the hydrolyzate of a commercial unbleached jack pine sulfate pulp. This presents evidence that, in at least one case, arabinose units are present in the cell walls of a coniferous wood.
KEYW Arabinose content, hydrolyzates, coniferous wood, cell walls, sulfate pulp.

671 AUTH Woo, J. Y.
DATE 1970
TITL Techniques for sectioning and staining tissue cultures of western white pine.
PUBL Research Note INT-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.
ABST Using transparent tape as a support, paraffin sections as thin as 5 mμ are microtomed from large, whole, and friable tissue cultures of western white pine and from pine cultures infected with blister rust fungus. Pathological differentiation is obtained with

Conant's quadruple stain or safranin 0-fast green stain, and cytological differentiation of the fungus is obtained with Heidenhain's hematoxylin stain or Flemming's triple stain.
KEYW Tissue culture, cytology.

672 AUTH Wood, K.
DATE 1959
TITL Canadian building timbers.
PUBL Wood. 24(8): 322-325.
ABST Major wood uses of the ten Canadian timber species are presented.
KEYW Building application.

673 AUTH Works, D. W., Boyd, R. J., Jr.
DATE 1972
TITL Using infrared irradiation to decrease germination time and to increase percent germination in various species of western conifer trees.
PUBL Transactions ASAE. 15(4): 760-762.
ABST Intense infrared irradiation of short duration promotes the germination of western white pine seed. The optimum exposure will vary from one seed lot to another; however, the variation is within narrow limits. An overexposure of irradiation will be destructive and cause devitalization. The degree of devitalization will increase as the exposure is increased.
KEYW Seed germination, infrared irradiation.

674 AUTH Wright, E., Graham, D. P.
DATE 1952
TITL Surveying for pole blight.
PUBL Journal of Forestry. 50: 680-682.
ABST The author concludes that observation and mapping of pole blight areas from the air, followed by inspection by ground crews, is the most complete and economical method of covering the region, including the most remote parts.
KEYW Pole blight, survey, mapping.

675 AUTH Wright, J. W.
DATE 1959
TITL Species hybridization in the white pines.
PUBL Forest Science. 5: 210-222.
ABST The results of 10 years of work on species hybridization with the five-needled pines at the Northeastern Forest Experiment Station are summarized. Including reciprocals, 38 different species combinations were attempted, of which 16 are regarded as successful or probably successful. Twelve of the 16 combinations have been authenticated in the nursery. Comparative trials were made of year-old pollen stored in a refrigerator or deep freeze and fresh pollen of the same species. In nearly all cases, total (filled plus empty) seed sets were similar for the two types of pollination; but sets of filled seeds were higher (appreciably so in three cases) after the use of fresh pollen than after the use of year-old pollen.
KEYW Hybrids.

676 AUTH Wright, J. W., Bingham, R. T., Dorman, K. W.
DATE 1958
TITL Genetic variation within geographic ecotypes of forest trees and its role in tree improvement.
PUBL Journal of Forestry. 56: 803-808.
ABST Summarizes known genetic variation within geographic ecotypes of forest trees. Cites work by Squillace and Bingham, which found statistically significant correlations between periodic annual increment of parents and height of progenies for western white pine.
KEYW Genetic variation, geographic ecotype, tree improvement, intraecotypic variation.

677 AUTH Wright, J. W., Gabriel, W. J.
DATE 1959
TITL Possibilities of breeding weevil-resistant white pine strains.
PUBL Research Paper NE-115. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 35 p.
ABST Western white pine shows the most immediate promise as a source of weevil resistance. It was studied in ten arboreta and forest plantings in New York and Pennsylvania. In all locations this species showed good climatic adaptability, growth rate, and bole form. It crosses easily with eastern white pine and is much less susceptible to blister rust. For the present it can be recommended for limited use in mixed plantings in areas subject to heavy weevil attack but with light *Ribes* populations.
KEYW Resistance weevil, white pine weevil, *Pissodes strobi*, provenance growth.

678 AUTH Young, V. A., Doll, G. B., Harris, G. A., Blaisdell, J. P.
DATE 1942
TITL The influence of sheep grazing on coniferous reproduction and forage on cut-over western white pine areas in northern Idaho.
PUBL University of Idaho Bulletin. 37(6): 46.
ABST Moderate grazing by sheep is beneficial to western white pine reproduction and has little effect on other coniferous species, but overgrazing is detrimental to the reproduction of all coniferous species, with white pine suffering least. The loss of coniferous seedlings due to sheep trampling was great-

est in the 1-year class and decreased as the seedlings matured to practically no loss at 5 years of age. In most cases, before direct coniferous seeding can be successfully practiced on badly overgrazed ranges, rodents must be controlled. Grazing may assist the reseeding of an area to white pine forest. Continuous overgrazing on most areas is not only harmful to coniferous reproduction, but the more palatable plants are replaced by less desirable ones. Certain browse species may produce two or more crops of leaves when grazed. Significant losses in wild black currant are caused by sheep grazing—especially overgrazing—but sticky currant is unaffected. Grazing does reduce fire hazard.

KEYW Grazing sheep, reseeding, ecological succession.

679 AUTH Zach, L. W., Bauer, D., Goodyear, H.
DATE 1943
TITL Practical application of plant hormones in forest-tree propagation.
PUBL Journal of Forestry. 41: 214.
ABST Seeds, cuttings, and 1- and 2-year-old seedlings of a variety of species were treated with indolebutyric acid to test the effectiveness of plant hormones in forest-tree propagation. Treatment results were mostly negative. Possible explanations were low March temperatures causing a reduction in hormone activity and a large amount of humus in the soil, which may have buffered the effect of the hormones.
KEYW Plant hormones, forest-tree propagation, indolebutyric acid, cuttings, seedlings, seeds, humus.

680 AUTH Zahner, R., Stage, A. R.
DATE 1966
TITL A procedure for calculating daily moisture stress and its utility in regressions of tree growth on weather.
PUBL Ecology. 47: 64-74.
ABST A method is described for computing daily values of moisture stress on forest vegetation, or water deficits, based on the differences between Thornthwaite's potential evapotranspiration and computed soil-moisture depletion. More realistic functions are used for soil-moisture depletion on specific soil types than have been customary. These functions relate daily rates of depletion to characteristics of soil-moisture tension. Separate functions account for surface soil wetting and drying processes following rain and dry periods. Two methods of summarizing the day-by-day distribution of moisture stress are illustrated. One utilizes directly accumulated stress values during such logical growth intervals as periods of leaf flushing or bud setting. The second method computes moisture stress and weather variables as functions of time over two growing seasons and utilizes the coefficients of orthogonal polynomials as independent variables in regressions of growth. In an example of western white pine basal area growth utilizing this latter method, moisture stress accounted for a 28 percent reduction in the variance of growth remaining after the effects of temperature and precipitation had been removed. The complete model accounted for 78 percent of the total variation.
KEYW Daily moisture stress, tree growth, weather, basal area.

681 AUTH Zavitkovski, J., Newton, I.
DATE 1969
TITL Effects of snowbrush on growth of some conifers.
PUBL Journal of Forestry. 67(4): 242-246.
ABST Findings indicate that snowbrush is more detrimental than beneficial in forest regeneration on west slopes of the Oregon Cascades.
KEYW *Ceanothus velutinus*, planted seedlings, natural regeneration, full occupancy suppression, competition, nitrogen fixing, nurse crop.

682 AUTH Zinkel, D. F., Spalding, B. P.
DATE 1972
TITL Anticopalic acid in *Pinus strobus* and *P. monticola*.
PUBL Phytochemistry. 2: 425-426.
ABST No anticopalic acid was found in the needles or cortex oleoresin of *Pinus monticola* from Lolo National Forest, MT. Anticopalic acid was previously reported as 55 percent of the resin acids in the wood of western white pine.
KEYW Anticopalic acid.

683 AUTH Zinkel, D. F., Toda, J. K., Rowe, J. W.
DATE 1971
TITL Occurrence of anticopalic acid in *Pinus monticola*.
PUBL Phytochemistry. 10: 1161-1163.
ABST Anticopalic acid, a labdane diterpene not previously reported in the gymnospermae, was found to be a major resin acid in the bark and in the wood of western white pine, *Pinus monticola*.
KEYW Anticopalic acid.

684 AUTH Zobel, D. B., Antos, J. A.
DATE 1982
TITL Adventitious rooting of eight conifers into a volcanic tephra deposit.

PUBL Canadian Journal of Forest Research. 12(3): 717-719.

ABST During the second growing season after the 1980 eruption of Mount St. Helens, *Abies amabilis, A. procera*, and *Pinus monticola* produced adventitious roots into tephra, the first known instance of rooting by these species. *Abies lasiocarpa, Chamaecyparis nootkatensis, Thuja plicata, Tsuga heterophylla*, and *T. mertensiana* also adventitiously rooted; *Pseudotsuga menziesii* did not.

KEYW Adventitious roots, tephra substrate.

AUTHOR INDEX

KEYWORD INDEX

☆U.S. GOVERNMENT PRINTING OFFICE: 1987-773 -039/ 61032

Hoff, Ray J.; Qualls, Janet I.; Coffen, Dale O. 1987. Western white pine: an annotated bibliography. Gen. Tech. Rep. INT-232. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 138 p.

This bibliography lists 684 articles, limited mainly to English. It includes unpublished theses and typewritten reports. References concerning white pine blister rust have been excluded unless they provide other data or information. An author and subject index are included.

KEYWORDS: *Pinus monticola,* bibliography

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

Forest Service

Intermountain Research Station

General Technical
Report INT-233

Guide to Understory Burning in Ponderosa Pine-Larch-Fir Forests in the Intermountain West

Bruce M. Kilgore
George A. Curtis

THE AUTHORS

BRUCE M. KILGORE received his bachelor's degree from the University of California, Berkeley, in 1952 in wildlife conservation, his master's degree from the University of Oklahoma in 1954 in journalism, and his Ph.D. from the University of California, Berkeley, in 1968 in zoology. From 1964 to 1968, he did research on the response of populations of breeding birds to prescribed burning in giant sequoia-mixed conifer forests. In 1968, he joined the National Park Service at Sequoia-Kings Canyon National Parks where he conducted research on the fire ecology of sequoia-mixed conifer and red fir forests of the Sierra Nevada in California. In 1972, he became Associate Regional Director for Resources Management and Planning for the Western Regional Office of the National Park Service in San Francisco. In 1981, he joined Intermountain Research Station, at the Intermountain Fire Sciences Laboratory, Missoula, MT, where he conducted research on use of prescribed fire in both natural areas such as Glacier National Park as well as use of prescribed fire in sagebrush-grass and pine-fir-larch types. He served as leader of a fire management in natural ecosystems project. In 1985, he accepted his current assignment as Regional Chief Scientist and Chief of the National Park Service's Western Region Division of Natural Resources and Research in San Francisco.

GEORGE A. CURTIS graduated from the University of Minnesota in 1958 with a B.S. in forest management. He joined the Forest Service, U.S. Department of Agriculture, on the Kootenai National Forest in 1958 where he has worked to the present time. Curtis has been a leader in the Northern Region of the Forest Service in promoting the use of and training of others in the use of prescribed fire in land management. He has served as an instructor at the Prescribed Fire Management and Fire Effects Course conducted in Missoula for all agencies and the private sector. Since 1962 he has prescribe-burned about 55,000 acres in the ponderosa pine/larch/fir type.

RESEARCH SUMMARY

This guide summarizes the objectives, prescriptions, and techniques used in prescribed burning beneath the canopy of ponderosa pine stands, and stands of ponderosa pine mixed with western larch, Douglas-fir, or grand fir. The guide is based on information from 12 Districts in seven National Forests in Montana and Oregon that have active programs of understory burning in several specific kinds of forest vegetation—SAF cover types (1954) 237, 212, 210, and 214, as well as 213 (SAF 1980).

The sizes of current programs ranged from more than 6,000 acres per year in the six districts in the Northern Region (Montana and Idaho) to nearly 36,000 acres in the six Districts in the Pacific Northwest Region (Oregon and Washington). Costs ranged from $2 per acre in spring burning to more than $250 per acre in fall burning. The guide covers cost management, resource management, fire objectives, burning constraints, and situations requiring great caution. The guide explains how to develop burning prescriptions based on the experience of burning experts, combined with recent findings at the Forest Service Intermountain Fire Sciences Laboratory, Missoula, MT (Brown and others 1985).

Topographic factors (aspect, slope, elevation), fuel quantity and moisture levels, weather factors, and timing all play key roles in developing a burning prescription.

Preburn preparation, involving thorough unit layout and planning, firelines, appropriate protection for leave trees, and other fuel treatment, combined with particular ignition techniques and firing patterns, is essential to successful understory burning in this vegetation type. Most experienced burners recommend starting with small units and building toward larger ones.

Good programs are usually tied to a positive attitude toward use of prescribed fire. Patience is essential in understory burning, and best results are often achieved with small crews.

It is important to know the relationship between fuel moisture and fuel consumption (Brown and others 1985). Understory burning in this forest type requires hard work and careful preparation. It may take two or three prescribed burns over an extended period of time to meet all desired objectives.

September 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

CONTENTS

Guide to Understory Burning in Ponderosa Pine-Larch-Fir Forests in the Intermountain West

Bruce M. Kilgore
George A. Curtis

INTRODUCTION

Prescribed fire is commonly used to manage vegetation in the Western United States. Objectives of this burning include fuel reduction, site preparation, range and wildlife habitat improvement, and esthetics (Noste and Brown 1981). This paper summarizes information on the use of prescribed burning beneath the canopy of ponderosa pine stands, and stands of ponderosa pine mixed with western larch, Douglas-fir, or grand fir.

This guide covers the four cover types (Society of American Foresters 1954) in Fischer's (1981) "Photo Guide for Appraising Downed Woody Fuels in Montana Forests," namely interior ponderosa pine (SAF cover type 237), larch—Douglas-fir (212), interior Douglas-fir (210), and ponderosa pine/larch/Douglas-fir (214). The 1980 SAF revision, however, eliminates cover type 214 and incorporates it into the other three types, and 212 is renamed western larch (SAF 1980). We also included the new grand fir type (213).

Similar types described by Burns (1983) are (1) northwestern ponderosa pine and associated species; (2) ponderosa pine and Rocky Mountain Douglas-fir; (3) western larch; and (4) grand fir, Douglas-fir, and associated species (eastern Oregon and Washington). Geographically, this guide covers eastern Oregon and Washington, northern and central Idaho, and western Montana, although many of the principles involved will extend far beyond that region, wherever the combination of ponderosa pine/larch/fir occurs. In addition to the Forest Service, this information should be of value to anyone using prescribed understory burning in various governmental agencies, and the private sector. The guide was written for District and Forest staff members involved in prescribed burning: fire management specialists, fuels specialists, silviculturists, and wildlife managers.

There have been many studies and publications on the impacts of prescribed burning in ponderosa pine in Arizona, California, Oregon, and Washington: Biswell and others 1973; Covington and Sackett 1984; Harrington 1982; Maupin 1981; Sackett 1980a; Weaver 1951, 1959; and Wright 1978. Harrington (1981) offered preliminary prescriptions for understory burning in ponderosa pine in the Southwest. Guidelines have also been developed for use of prescribed fire in the South (Mobley and others 1978) and the Southwest (Southwest Interagency Fire Council 1968). Fischer (1978) and Martin and Dell (1978) discuss factors involved in planning and evaluating prescribed burns.

In the Intermountain West as early as 1966, Beaufait made use of interviews of fire specialists who had done extensive broadcast burning in clearcuts. By contrast this current publication tells how 12 experienced specialists burn effectively beneath canopies of living trees in Montana and Oregon without damaging the overstory species they wish to maintain.

Like Beaufait (1966), we recognized the value of the personal insights of those who have successfully planned and carried out prescribed burns in these vegetation types. Of equal concern was the feeling that unless this information was gathered and recorded soon, many of the most experienced individuals would retire or move to other assignments. Thus the forestry profession might lose the opportunity to pass their knowledge and guidance to newcomers wanting to use prescribed fire beneath canopies of pine/larch/fir.

From two Regions and seven National Forests in Montana and Oregon, we selected for interview the staffs of 12 Districts known to be conducting understory burning in the forest type of interest. We interviewed a team made up of the fire management officer (FMO), silviculturist, and wildlife specialist. Our questions are included in appendix A; the Districts and individual staff members are noted in appendix B.

The respondents typically had from five to 20 seasons of prescribed burning experience, with at least 5 years in understory burning in the pine-larch-fir type. We usually spent 5 to 8 hours with personnel in each District, recording answers to the 14 major questions and the more than 80 subquestions. These answers were summarized in chart form and sent to all participants. This was followed by a 2-day workshop in which various facets of the problems in prescribed burning in these types were discussed, together with a comparison of similarities and differences in prescriptions and techniques. Finally, a draft report was sent to all participants for review, comment, and final revision.

Because of the great variety of vegetative and environmental circumstances, no single approach to burning will always work best in this forest type. Nevertheless, the information from the interviews, the workshop, and the literature will provide invaluable guidance to conducting burning programs and avoiding pitfalls.

In understory burning, there is a tendency to think in terms of the "natural" fire cycle. For example, if fire is known to have occurred every 6 to 25 years during the past 200 years or so, managers may assume they should burn on a "stand maintenance" basis at similar intervals.

But in many stands, managers will need to use understory burning before or after activities such as logging or wildlife, range, and recreation improvements.

Although the season of burning may vary among sites and vegetation types (see later discussions of prescriptions), the risk of escape is much less in spring than fall in ponderosa pine types. In addition, the potential for smoke pollution is much reduced. This guide, therefore, is mainly devoted to spring burning, with some discussion of circumstances that warrant fall burning.

SIZE AND COSTS OF CURRENT PROGRAMS

The 12 Districts we visited comprise about 4 million acres of commercial National Forest lands in eastern Oregon (Pacific Northwest Region) and western Montana (Northern Region). About half of this, 875,000 acres in the Northern Region (R-1) and 1.3 million acres in the Pacific Northwest Region (R-6) represents the pine/larch/fir type (appendix C). Prescribed fire in some form is currently used on more than 6,000 acres per year in R-1 and nearly 36,000 acres in R-6. Of this, about 2,400 acres involves understory burning of pine/larch/fir in R-1, and 9,200 acres involves understory burning of this type in R-6. The pine/larch/fir type comprised about 85 percent of the R-6 Districts, while this type was found on less than 40 percent of R-1 Districts, except the West Fork which is 75 percent pine/fir.

Spring burning costs ranged from \$2 to \$35 per acre in R-6, and from \$2 to \$70 per acre in R-1 (appendix D). Fall burning costs, on the other hand, ranged from \$35 to \$250 per acre in R-6, and from \$25 to \$250 per acre in R-1. Fall burning is generally needed to prepare sites on north and northeast aspects for natural regeneration. Differences between spring and fall costs usually relate to needs for additional firelines and mopup in the fall (see appendix D for specifics from each District).

Opportunities to reduce cost that the experienced prescribed burners felt were highly important were these:

1. Use natural or ready-made firebreaks rather than build fireline.

2. Pick weather conditions that allow you to achieve objectives with a minimum of line building and little or no mopup. This usually means spring burning with a small crew.

Figure 1—Large units (200-500 acres or more) can be ignited with the helitorch in natural fuel loadings of 7-15 tons/acre.

3. Set a minimum size for the burn below which burning is not economical. Some suggest 200 acres as a minimum for wildlife habitat improvement burns. This is cost efficient because a burn can usually be completed during a single 4- to 8-hour burning period. With today's aerial ignition systems (Mutch 1984), units of 400 to 500 acres on steep, inaccessible terrain can be burned during a single burning period (figs. 1 and 2).

4. Avoid false starts by careful planning and by monitoring burning conditions from Remote Automatic Weather Stations (RAWS) (Warren and Vance 1981) or other indicators of weather/fuel conditions. RAWS units collect weather information and transmit the data automatically via satellite to distant recording sites where managers can use the data to make decisions on timing of prescribed burns.

Figure 2—The Mark II Ping Pong Dispenser, mounted in helicopter and ready for use, requires only one operator. A newer unit (Mark III), which has a larger, vibrating hopper and requires less maintenance, is now available.

5. Consider use of aerial ignition on units greater than 100 acres. This allows multiple unit burns and wider prescriptions. (The Yaak District also suggested having multiple units ready, particularly on helitorch burns, to allow alternate burn sites, thus avoiding false starts.)

6. Spring burns are generally less expensive than fall burns, providing conditions are right for reaching the objective.

7. Consider the percentage of live crown scorch and bole damage various species can handle before incurring costs of expensive prefire treatments such as lopping, protecting leave trees, or yarding unmerchantable timber (YUMing).

OBJECTIVES OF UNDERSTORY BURNING

Resource Objectives

Expert practitioners in R-1 and R-6 list three main resource objectives and a wide assortment of secondary objectives for understory burning. Primary objectives are (1) fuel reduction, both natural and activity (slash) fuels; (2) site preparation for conifer regeneration; and (3) range and wildlife habitat improvement. Secondary objectives given by one or more practitioners were (4) timber stand improvement (TSI), including thinning (fig. 3), mistletoe control, etc.; (5) insect and disease abatement; (6) species manipulation (trees, grass, shrubs); (7) esthetics; and (8) recreation (campground burning). These broad land management or silvicultural objectives are derived from goals of the organization and tend to focus on composition, amount, and arrangement of vegetation and fuels over time (Brown 1984).

Although insect and disease abatement is usually considered a secondary objective, some prescribed burners thought that fire plays a major role in controlling insects and diseases, particularly in R-6. Among the benefits they reported were eliminating habitat of ips beetles (logging slash); reducing sources of heart rot fungi (stumps, snags, and down wood); reducing white fir in pine forests, thus reducing root rots; preventing interlocking crowns, and thus inhibiting movement of spruce budworm between stands; maintaining more open stands (fig. 4) and thus more healthy trees, which can pitch out beetles; and ridding stands of mistletoe. The primary adverse impact occurs during the year following the burn, when many prescribed burners note an increase in beetle populations in older, low-vigor, or fire-damaged trees. This is usually a short-term impact, however, that generally has little effect beyond the first year. Timing of burning in relation to beetle life cycle can often minimize severity of beetle attack.

Figure 3—Ignition in early spring, using a strip-head fire in 5-12 tons/acre of old thinning slash, in a pole-sized stand of ponderosa pine and Douglas-fir.

Figure 4—Spring understory burning in the ponderosa pine and Douglas-fir type, with bitterbrush and bunchgrasses on site. Dense pockets of pole-sized trees are torching out in fuel concentrations. The objective of such burning is to maintain an open-grown and healthy (disease-free) stand.

Fire Objectives

Once the broader resource management objectives have been decided, prescribed burners must translate these into specific treatment objectives. For example, the broad objectives might be to reduce organic materials or fuels and to kill certain sizes and species of plants. Examples of specific fire objectives would be to consume 50 percent of fuels less than 3 inches diameter, to expose 20 to 30 percent mineral soil, and to kill 60 percent of the shade-tolerant understory conifers less than 3 inches diameter at breast height (d.b.h.).

Setting these broad and specific objectives for a given burn or for an entire program is done by an interdisciplinary team approach, in which representatives of the various benefiting functions meet and plan the burn within the context of the Forest Plan or the overall area plan. These same individuals, often representing timber, silviculture, wildlife, fire, and any other functions logically involved, also set monitoring criteria and evaluate how well the burn met the objectives. The experienced prescribed burners felt it was important to set measurable objectives that are attainable, simple, and realistic to meet land managers' needs. They felt that political issues such as important esthetic views, smoke-sensitive areas, and budget concerns need to be taken into account, prior to setting fire objectives. There might be instances when burning would be delayed to avoid particular weather conditions or the timing of a local community event.

Situations for Fire Use

Appropriate objectives and successful burning prescriptions and techniques depend on an accurate understanding of fire effects and how they relate to your particular environmental situation. There are a number of situations in the pine/larch/fir region in which understory burning can be used very effectively. Other situations require great care to avoid undesirable effects. Three stand conditions in which prescribed burners in Regions 1 and 6 now use understory burning are:

1. Ponderosa pine, with surface fuels of grass, brush, or duff (fig. 5).
2. Ponderosa pine and western larch, mixed with grand fir, white fir, or Douglas-fir (fig. 6).
3. Mixed conifer, with a small amount of ponderosa pine (fig. 7).

Figure 5—A 20-year-old pole-sized stand of ponderosa pine, Douglas-fir, and bitterbrush being burned in the spring to reduce high fuel hazard adjacent to a recreation site at minimal cost.

Figure 6—Spring understory burning in ponderosa pine and associated species removes fir invading key range and wildlife habitat.

Figure 7—Spring burning in a mixed conifer type in natural fuels. The objective is to maintain some small openings by burning, or logging and burning, on a 15- to 25-year cycle.

These three situations represent progressively more complex burning situations in which it becomes increasingly more critical to define specifically what the objectives are, and, in turn, how to achieve them without increasing the risks of undesirable effects.

Situations Requiring Caution

The fire specialists interviewed described the following series of conditions—usually not typical ponderosa pine or seral pine situations—in which they felt great care (caution) was required to use understory burning without undesirable effects:

1. Use of fire to thin stands of pure grand fir (or white fir) forests. (These species have low resistance to fire; cambium damage is sometimes followed by disease within 1 to 2 years after fire.)
2. Understory burning beneath lodgepole pine, white pine, spruce, and cedar-hemlock. (These species are easily damaged by fire because of thin bark or crown characteristics that lead to excessive scorch.)
3. Duff reduction on north slopes, with high fuel loading. (This can be expensive and complex; the overstory may be killed unless an initial low-intensity understory burn is used to reduce heavy fuel loads prior to a harvest or thinning operation, followed by a second burn to clean up activity fuels.)
4. Burning areas that include mountain-mahogany. (Here the short-term killing of the individuals must be balanced against the longer term importance of fire to rejuvenation of the species [Gruell and others 1985]).

SUCCESSFUL BURNING PRESCRIPTIONS

The experienced prescribed burners felt that developing successful burning prescriptions requires a professional approach by a skilled fire manager trained in fire behavior and fire effects. Prescriptions normally consist of fuel and weather parameters such as fuel moisture, windspeed, relative humidity, and temperature (see table 3 in section Weather Factors). Through use of fire behavior prediction techniques—including the BEHAVE system—some managers now prefer to use predicted flame lengths and rates-of-spread as prescription criteria. Whichever is used, the prescriptions still require specific high quality fuels, topography, and weather data collected by field personnel. Poor field reconnaissance and inadequate field data reduce your chances of meeting your burn objectives. Prescribed burners stressed that poor quality data and poor prepara-

tion have no place in today's prescribed fire programs.

Successful prescribed burners use site-specific data in combination with first-hand experience and expertise, from themselves and others, to arrive at acceptable prescriptions for the expected fire behavior. They need to use the best tools to predict both duff and woody fuel consumption (Brown and others 1985). Today's challenge is to develop practical prescriptions that will accomplish objectives within a reasonable time and that are cost effective. If you want to accomplish several objectives with a complex prescription, however, you must be willing to compromise and be willing to burn two or even three separate times in some areas before you meet all your objectives.

How To Develop Burning Prescriptions

Experienced prescribed burners noted that in developing prescriptions, the first step is to gather resource data (a quick inventory of trees, shrubs, and so on in the area) from those specialists directly involved in a project. The next step is to clearly distinguish fire objectives from broader resource objectives. Fire objectives spell out how much organic material should be consumed and what vegetation should be killed or left alive (Brown and others 1985). Then constraints—such as the need to control the fire and how much duff and large woody materials will remain on site—must also be clearly defined. Once you have defined how much duff and woody material will be removed (and how much will be left), you can use the known relationships between duff moisture content and NFDR 1000-hour moisture, on the one hand, and duff depth reduction and mineral soil exposure on the other to help develop your prescription (these relationships and predictions are summarized in Brown and others 1985).

Any conflicts between objectives, or between objectives and constraints, must be resolved before selecting the weather and fuels parameters for your ignition method. For example, you may want to burn at higher fuel moisture to prevent escape of fire and reduce crown scorch, but in so doing you increase smoke production. Thus the objective of protecting certain trees, and the constraint to reduce risk of fire escape, may both conflict with the constraint to minimize smoke production (Brown 1984). Priorities must be set for both objectives and constraints, and compromises will often be needed. The greatest challenge in the development of a "prescription window" for understory burning is to keep it simple. (By "prescription window," we mean the range of fuel moistures, windspeeds, relative humidities, and temperatures that will allow the type of fire behavior necessary to accomplish the desired objectives - see table 3.) A go/no go checklist/chart or a simplified plan which clearly lays out: (1) site specific fuels, (2) weather, and (3) supplies and equipment needed for the burn can help the burn boss decide whether or not to burn.

Practitioners also pointed out that it is important to have a wide enough "window," meaning a range of weather and fuel parameters so there will be at least three or four opportunities to complete the burn. If the job has been carefully planned and prepared, the land manager should have several good burning days in a season when objectives can be met. Narrow prescription windows seldom allow timely completion of understory burning. Prescriptions should be tested against such climatological weather programs as RXWTHR/RXBURN (Bradshaw and Fischer 1981).

Size of the unit to be burned is an important consideration. Units should be of a size that can be burned in one day. This allows maximum control of ignition method and ignition rate.

CONSTRAINTS: AIR QUALITY/SMOKE

In planning and conducting prescribed burns, the prescribed burn boss must be mindful of the Clean Air Act (Public Law 95-95) and the public interest (Ferry and others 1985). Beyond this, he must use both professional and ethical judgment in carrying out these duties. Because prescribed fires produce smoke, the future of prescribed burning programs depends on how effectively the amount and direction of smoke is managed.

Although smoke management must be considered in every prescribed fire plan, not all smoke is bad (Ferry and others 1985). Fire and the resultant smoke is an integral part of many ecosystems and cannot be separated from such ecosystems without some consequence. Pine/larch/fir usually can be burned during favorable conditions in spring when air quality is not a problem. Prescribed fire managers and burn bosses should consult the Prescribed Fire Smoke Management Guide recently published by the Prescribed Fire and Fire Effects Working Team of the National Wildfire Coordinating Group (Ferry and others 1985) for methods for preventing or mitigating the adverse impacts of smoke on human health and welfare. The guide can also be helpful in developing techniques to meet smoke management objectives for individual prescribed fires.

SOURCES OF INFORMATION

The TI-59 (Burgan 1979) was mentioned by eight of the 12 Districts as helpful in developing prescription windows, often combined with the newer BEHAVE (Rothermel 1983) program (three Districts). (The HP-71B will soon replace most TI-59's.) It was used to estimate flame lengths and intensities, both inside and outside the prescribed burn. The TI-59 and BEHAVE, however, do not take ignition patterns into account in their predictions, and experienced prescribed burners think that you need to compensate for this. Nomograms are also useful, because they display the sensitivity of fire behavior to windspeed and fuel moisture. Fire specialists on six Districts thought it important to heed experience, gut feelings, and seat-of-the-pants judgment, often of the most experienced prescribed burner on the district. This experience was relied on for determining the best estimates of appropriate weather factors (wind, relative humidity, temperature, and precipitation), season of burning, and ways to apply information from the various written sources noted below.

Four of the six R-1 Districts interviewed used Norum's (1977) guidelines to determine burning conditions needed for reducing duff and exposing mineral soil as desired. Fischer's (1981) and other photo series helped them to determine fuel loading and to judge whether understory burning was practical or not in these situations. The 13 fire behavior fuel models (Albini 1976; Anderson 1982) were useful in estimating intensities and scorch heights, as

were Albini's nomograms and Bevins' (1980) charts for scorch heights for Douglas-fir. Other sources of prescription information mentioned by one or more districts were Volland and Dell's (1981) fire effects of Pacific Northwest vegetation, area guides to plant associations and management (for example, Hall 1973), guides to habitat types and succession (R-1), R-1 fuel management guides, the debris prediction and HAZARD programs, the down woody inventory system (Brown 1974), 10-hour fuel stick data, moisture meter data, and fuel moisture charts. The Superior District of the Lolo National Forest in Montana uses several charts developed by Ralph Parkin, which integrate fuel moisture, relative humidity, and temperature into a prescription window (fig. 8).

The most current and complete description of how to design a fire prescription available at this time is Jim Brown's "A Process for Designing Fire Prescriptions" (Brown 1984). This report comprises ideas drawn from several references and from interviews of field specialists. Brown's procedure is easy to use and will produce a prescription that will achieve 80 to 100 percent of your objectives.

		FUEL MOISTURE, 8-12 (10-HR FUELS)						
TEMPERATURE		50°	55°	60°	65°	70°	75°	80°
HUMIDITY, %	20	X	X					
	25	X	X					
	30	X	X	X	X			
	35	X	X	X	X	X		
	40	X	X	X	X	X		
	45	X	X	X	X	X	X	
	50	X	X	X	X	X	X	X
	55		X	X	X	X	X	X
	60				X	X	X	X
	65					X	X	X
	70						X	X
WIND, 0-8 MI/H								

Figure 8—Desirable combinations of weather and fuel moisture for spring understory burning for wildlife in Fuel Models 1 and 2 on the Superior District of the Lolo National Forest. These are site-specific charts; to be effective, they should be modified for use on each District or Forest.

GENERAL CONCEPTS

The following broad guidelines and techniques should be considered in all prescriptions for understory burning and should be incorporated in the burn plan (see appendix E for sample burn plan):

–Decide on broad land management objectives, whether it be regenerating trees, improving wildlife or range habitat, or reducing fire hazard (Brown 1984).

–Resolve conflicts in such land management objectives for all resource areas, keeping in mind that there is usually more than one way to accomplish a specific objective.

–Write the site-specific silvicultural, wildlife, or range prescription for each stand or unit.

–Decide on your fire objectives (or treatment objectives), such as consumption of organic material and killing plants (Brown 1984).

–In writing successful prescriptions, it is important to know and use the relationships between fuel moisture and fuel consumption (Brown and others 1985). These along with windspeed help to determine the fire intensities and flame lengths you need to achieve your fire objectives.

–If your objective is to save critical species in certain d.b.h. and height classes, burn before bud burst in spring or in late fall when trees again become dormant.

–Use appropriate technical aids in preparing your prescription (see Brown 1984; Brown and others 1985). These can't entirely replace experience or consultations with other successful prescribed burners, but they will "get you in the ball park" or warn you of a potentially hazardous situation.

–Know what constraints affect the fire prescription, such as controlling the fire and managing smoke production.

–If some of your weather and fuel prescription parameters are at the high end of the range, then others should be at the lower end (example, fig. 8). Avoid using extreme ends of the weather and fuel parameters together (highest winds with lowest fuel moisture). A fire behavior prescription, such as flame length or rate-of-spread, calculated from a TI-59, HP-71B, or BEHAVE program, will alert the user to potential fire behavior problems, both inside and outside the unit. Ignition patterns and methods are also important factors here and will help you decide whether or not you can reasonably burn.

–Remember that in understory burning wind is usually needed to reduce scorch heights. This is true because, when other factors are constant, an increase in wind will increase flame length, but decrease flame height and thus scorch height. This occurs, in part, because heat will dissipate laterally rather than straight up through the canopy.

–If you are a newcomer to the District or unit, talk to some of the old-timers in the area. They may have valuable knowledge of local weather conditions; while such information is not uniformly accurate, it could benefit your burning program. The logging contractor or permittee may also be a valuable source of information.

–Do not learn by trial and error when others have developed successful techniques. This is not to say that even the more experienced burners may not need to try something new, especially to accomplish a special objective or test a new idea. Nevertheless, under ordinary circumstances, problems can be solved by consulting the several expert prescribed burners in the Intermountain West who are willing to share their skills and knowledge with others (see appendix B).

–Make a complete reconnaissance of the burn unit to be sure you have adjusted the factors of fuels, weather, and

topography to fit on-site needs. Allow adequate time for this, so land managers can accomplish their objectives with good results, not just blackened acres.

–Make your prescription window broad enough to allow several opportunities in a season to complete the burn, yet narrow enough to still obtain your objectives.

–Where new slash fuels are involved, ensure that the unit has been properly prepared for burning at least 30 days prior to the actual burn. This is the minimum curing time needed to dry slash fuels and meet air quality standards. Natural barriers, such as streams, ridges, and open rocky areas, or constructed firelines are needed to control, contain, or confine the burn. These should be planned and constructed far in advance and not left until the day of the burn.

Primary Guidelines

TOPOGRAPHIC FACTORS

Aspect—All experienced burners agreed that exposure largely determines the time of year to burn with assurance of safety and success. On south and west aspects, opportunities to burn are excellent in the spring in pine/larch/fir types. Extensive hand- or machine-constructed firelines are generally not needed, because you can tie into existing roads or natural barriers. Duff depths are generally shallow, and therefore the prescription should insure that duff is not completely consumed on these sites. Success on these aspects is high when burning is completed in the early spring following snowmelt and prior to greenup and bud burst.

Prior to organized fire suppression in the early 1900's, natural fires on these aspects occurred at 5- to 25-year intervals. This kept the stands open and maintained browse species in good condition for wildlife. One District in Oregon reported that wildfires greater than 1,000 acres in size occur on south and west aspects at about 10-year intervals. Natural fuels on these aspects are easy to treat with understory burning, and therefore should be very cost efficient.

All fire specialists said that north and east aspects should normally be burned in the late summer or early fall for best results. Stands on these aspects consist of more white fir and Douglas-fir than those found on south and west aspects, and the canopy on the north and east aspects is normally closed. Both fuel and duff depths are also greater than those on south and west aspects. Although high-intensity fires are possible in an unusually dry spring, understory burns in this type during the summer and fall will tend to be of higher intensity, because fuels are usually drier and the weather hotter; firelines are usually required. These aspects have a wider variety of species, and chances of total success in meeting land management objectives are much lower due to the complexity of the understory burn. One District in northern Idaho reported that only narrow prescription windows in late August or early September (after the first wetting rain) are available for burning north slopes.

Slope—In the Intermountain West pine/larch/fir stands are found on slopes that vary from essentially flat and rolling to steep—often in excess of 70 percent. Experienced burners use slope to control understory burns; without slope or strong winds, fire tends to burn slowly and in erratic directions. In this forest type wind is critical to effective burning on slopes of less than 20 percent; such minor slopes require eye-level winds of 5 to 15 mi/h to prevent heat damage/crown scorch problems. Without wind, prolonged heating at one location can lead to unacceptable scorching of the trees above.

Less wind is needed on slopes steeper than 30 percent; however, afternoon upslope winds are commonly 5 to 15 mi/h at eye level and tend to make the total job easier. This should be considered and adjusted for in developing prescriptions. Slope also tends to allow more burn days to accomplish targeted burn acreage.

Several fire specialists also warned that on slopes steeper than 50 percent, you should be aware of the potential for crown scorch on the upper portion of a unit where smoke and heat is funneled up through the canopy. Rock cliffs and dense pockets of trees on steep slopes can also funnel heat up through the crowns causing excessive scorch without winds of 5 mi/h or more. On steep slopes, the ignition of narrow strips in a downslope direction (see figure 12) is the best method to control scorch in the canopy. Extremely steep and rocky slopes are often given priority for wildlife habitat. Under this priority, some timber kill and a mosaic burning pattern may be desirable.

Elevation—Prescribed burners' comments on elevation varied from no concern to much concern about how elevation affects understory burning. Many of those interviewed showed a preference to burn at elevations below 4,500 feet in the spring and at higher elevations in the fall. This is partly the result of earlier and better access to lower elevations. With the present variety of ignition methods, however, including aerial ignition, access is not such a major problem. While costs need to be considered, personnel and ignition devices can be flown into the burn unit just prior to ignition.

Nevertheless, in spring, as snow melts, lower elevations are more readily accessible and fuels also dry out earlier there. Land managers need to be prepared to burn within a week after snowmelt on south, southwest, and west aspects, before greenup occurs. This period can begin as early as March in lower elevations and run through June at higher elevations.

Burning can take place in fall—often on north and northeast aspects—when fine fuels are cured out following summer heat and sometimes fall frosts. Fall conditions can provide the correct range of fuel moisture and temperatures to allow burning without consuming all the duff layer.

This difference in elevation can allow the land manager an opportunity to build a program of understory burning for each season, with an array of burn units at different elevations and aspects. This means that some units are almost always ready to burn under individual site-specific weather and smoke management considerations.

In late summer or fall burns, you must consider the thermal belt, which is the middle third of the slopes for these forest types (Barrows 1951). This zone can be extremely dry, with high potential for escaped fires. The influence of elevation on timing of burns and in turn on needs for building fire lines and for mopup can have a

major impact on costs of burning, and therefore must also be considered in setting priorities for understory burns.

FUEL FACTORS

Data Needed and Collection Methods—The prescribed burners interviewed had good knowledge of fuels, particularly how (1) quantity of smaller (less than 3-inch diameter) fuels, (2) arrangement, and (3) moisture content relate to fire intensity and, in turn, the ability to achieve objectives while retaining control. Such specialists thought that they needed data on quantities of down woody fuels, both natural and activity, and estimated or measured fuel moisture, including duff moisture. One District's specialists also indicated a need for estimates of crown density or stand density. A good general reference on fuel appraisals is the Northern Region Fuels Management Planning and Treatment Guide (USDA 1987).

Table 1 summarizes the methods most prescribed burners are using to obtain the data they consider important. Data on fuel quantity and such tools as QDEBRIS, HAZARD, and BEHAVE are used primarily to determine prescription limits for control of fire and for estimating tree mortality. Data on fuel and duff moisture, by contrast, can be used to predict whether you can achieve desired duff reduction and mineral soil exposure objectives (Brown and others 1985). The following comments on several of the most common fuel data collection methods used by the fire specialists may be helpful.

1. *Photo series with good field reconnaissance*—This method is used by most prescribed burners to get reasonable estimates by fuel size class. It is fast and reliable if reconnaissance is good and your eye and judgment have been calibrated on line intercept plots.
2. *Down woody inventory (Brown 1974)*—A precise method to obtain loading information on materials currently on the ground. It takes a minimum of 15 line intercept plots for an accurate estimate, which adds to cost and time requirements.
3. *Debris prediction (QDEBRIS)*—This is an acceptable method for estimating loading produced by logging activity. But stand examination data or sale cruise data are needed. This method is not widely used for understory burning because of lack of good site-specific stand data. (See Puckett 1977 and Fuels Management Planning and Treatment Guide, USDA 1987.)
4. *HAZARD program*—This program describes potential fire behavior for untreated debris or for lopped debris. Input for this system is the debris potential from the activity fuel (data from a standing tree inventory) and down fuel data. (It will not work with down fuel data alone.) (See Fuels Management Planning and Treatment Guidebook, USDA 1987.)
5. *Fuel modeling*—Most experienced prescribed burners use one of the standard 13 fire behavior fuel models (Albini 1976), or combinations of fuel models 2, 8, 9, 10, 11, and 12. Such modeling can produce estimates of fire behavior, particularly in fuels adjacent to your prescribed burn area, and thus identify possible escape problems. This technology is good if used with practical experience and knowledge of the fuel type involved; it has been used with fair to good results for understory burning.
6. *BEHAVE*—This fire behavior prediction and fuel modeling system allows modifications or combinations of the 13 standard NFFL fuel models; in fact it allows you to build your own site-specific fuel model. Although a good system, it is just now beginning to have wider use for understory burning. If standard fuel models are used for spring understory burning in this type, most of the experienced prescribed burners found BEHAVE to overestimate flame length, fire intensity, and rates-of-spread. Several experienced prescribed burners interviewed noted that the BEHAVE system was developed for wildfires during the critical fire season and assumes you have a homogeneous and continuous fuel bed. Through use of custom fuel models, however, BEHAVE can yield an acceptable range of predictions, although highly qualified personnel are needed to decide when such predictions are reasonable.

Table 1—Methods used by interviewed burners for obtaining fuel data

Data needed	Methods
Quantity of down woody fuels (mainly <3" diameter loading)	–Estimate by photo series (six Districts) –Ocular estimates (five Districts) using fuel models –Occasional calibration of the eye/judgment needed for the two estimate methods by using a few line intercept plots (but not using this as actual method)
Quantity of activity fuels	–Various debris and fire behavior prediction programs, such as QDEBAIS, HAZARD, etc. –Stand exam data (13-15 plots/150 acres)
Crown density or stand density	–Estimate from aerial photos
Duff moisture	–Computrac (Region 6 Districts) (Sackett 1980b) –Bob Martin's chart (Martin 1982) –Rod Norum's chart (Norum 1977) –Rough field estimate methods (here, several Districts felt need for "quick-read duff moisture meter")
Fuel moisture	–Delmhorst moisture meter (some use 16-21 plots) (Clark and Roberts 1982) –Charts for 1-hour fuels –10-hour fuel sticks

Consumption Estimating Tools—Achievement of fire objectives often calls for fuel moisture measurements from which to predict duff consumption and mineral soil exposure (Brown and others 1985). Knowledge of duff moisture content, for example, is essential for successful site-preparation burns. Several burners are using the Computrac moisture analyzer, the microwave oven technique, or standard drying oven to estimate field duff moisture conditions. (Several respondents had major problems with the microwave techniques.) These, in turn, are used to predict mineral soil exposure, based on relationships between duff moisture and burnout described by Norum (1977) and updated by Brown and others (1985). While there is considerable variation in both field conditions and sampling techniques, generally such predictions will be within 20 percent of the actual percentage of mineral soil exposed, and in most cases this is satisfactory. Although this process takes time and careful sampling, it is essential to achieve site preparation objectives.

If duff depths are less than 1 inch, a light burn (blackened surface fuels) will result in duff decomposition in 1

year. If duff depths exceed 2 inches and mineral soil is needed for site preparation, the unit should be burned in the fall. Remember that logging activity may have accomplished some site preparation even before burning. Spring burns with high duff moisture and soil moisture will seldom remove more than 50 percent of the duff layer (thickness). But it is seldom necessary or desirable to expose mineral soil over an entire burn unit to achieve desired stocking levels of most conifer seedlings.

Fuel Modeling as a Planning Tool—The custom fuel models developed using BEHAVE predict the effects of fuel loading and weather parameters on the related fire behavior parameters. Such rates-of-spread and flame lengths can then be used to predict impact on the stand prior to the understory burn. In combination with knowledge of flame length/crown scorch relationships, BEHAVE can be used as a planning tool. It helps managers evaluate whether the planned treatment will meet the constraints of the unit managers; it helps evaluate tree mortality and difficulty of control. It does not indicate whether fuel consumption and site preparation objectives can be met. These must be determined by estimating fuel consumption, as described earlier (Brown and others 1985). Nevertheless, BEHAVE has great potential in understory burning because it allows you to try various combinations of fuels and weather parameters until you find the combination that will produce a fire intensity that will accomplish site-specific objectives but not destroy the stand. The most successful burn specialists generally use a combination of standard fuel models or custom fuel models when they want the most accurate fire behavior predictions.

As an example, through the BEHAVE system, the Fremont National Forest in R-6 is using a combination of fuel models 2, 8, and 9 in understory burning for reduction of natural fuels. In activity fuels, they are using a combination of models 11, 12, and 13. These fuel models are specific to the Fremont Forest in R-6 and should be carefully analyzed prior to being used elsewhere. Prescription parameters on the Fremont are fire behavior outputs, not weather parameters. The BEHAVE system has given land managers excellent fire behavior outputs for predicting site-specific fire behavior. Custom fuel models in effect identify more burn days, because they depend solely on predicted flame lengths and scorch heights, not individual weather or fuel moisture limits. This prescription development system still requires highly qualified prescribed burn specialists at the site if used during the critical fire season. Why? Because fuel modeling is not an exact science, and human expertise must be applied when using model outputs at the upper end of the prescription window during the dry summer period.

Rules of Thumb Concerning Fuels—Several fire specialists have described some "rules of thumb" concerning fuels when deciding to burn or not to burn. The trial and error methods used in the past have produced some rough but practical guidelines for understory burning. Table 2 shows some of these rules of thumb that relate to constraints on fuel loading by size class.

It is extremely important for fire managers to get away from their desk and sample fuel conditions on the burn site prior to any understory burning. Many experienced burners can tell by walking through the planned burn site if the fuel and weather parameters are acceptable. The following are some simple procedures and observations that sometimes prove useful:

Pine needle check—As you walk through your planned burn area, pick up cured needles at different points and make this simple test: Hold a dead pine needle (past year's litter crop) with your thumbs about 1.5 inch to 2 inches

Table 2—Some rules of thumb for minimum fuel moistures required in difficult fuel situations (heavy loading of dry fuels) in understory burning in pine/larch/fir or associated species

Size of fuels	Fuel quantity	Concern for leave trees	Minimum acceptable fuel moisture	Advice for hazardous fuel situations[1]
	Tons/acre		*Percent*	
1. Less than 3-inch diameter fuels	>20	very high	10 h ≥16	Seldom occurs in this forest type; if it does, schedule burning at night or under high moisture conditions in the 10-h fuels.
2. Less than 3-inch diameter fuels	15-19	high	10 h 14-18	Use extreme caution when thinning trees <4 inches d.b.h. and 20 feet height.
3. Less than 3-inch diameter fuels	10-14	moderate	10 h 12-16	Use caution in mixed conifer understory; fire intensity and scorch may eliminate smaller Douglas-fir or white fir.
4. Less than ¼-inch diameter fuels	5-10	high	1 h 9-14	Caution! May exhibit fast rates-of-spread, with high intensity. Be careful in mixed conifer types.
5. Greater than 6-inch diameter fuels	5-12	high	1,000 h 20+	Some large fuels needed on postburn site for silvicultural reasons (Harvey and others 1979a,b; Jurgensen and others 1979).
6. Total fuel loading	>50 >30	very high moderate	10 h 13-17	Burn under higher moisture conditions to reduce intensity and scorch.

[1]Such fuels should be noted on the aerial photo or map of the burn unit.

apart (see fig. 9). Bring thumbs downward and together. If the needle breaks cleanly within a one-quarter arc, the needle is in the 4 to 7 percent fuel moisture (F.M.) range. If it continues to bend, but cracks sharply within one-half arc, the needle is about 8 to 11 percent F.M. If the needle continues to bend more than one-half arc, your fine (1-hour) fuels are too wet to burn. In making your initial pine needle checks, you may wish to confirm these F.M. percentages by also drying some needles in a standard drying oven for comparison. This will give you confidence in the readings you get from the needle test. In many situations, ponderosa pine needles will crack sharply within 2 or 3 days following snowmelt or a wetting rain. If ponderosa pine needles are between 4 and 10 percent F.M., they will also crack sharply as you walk through the stand.

Dry stick test (Fremont National Forest)—On the burn site, find a dry one-half to 1 inch in diameter stick or branch and hold it with your hands 18 inches apart. Pointing the stick away from your face and other personnel, bend the ends towards each other until it breaks. If it breaks in two places and the middle section jumps about 10 feet, your fuels may be too dry for burning. If the stick simply breaks in two places or cracks sharply in one place, the fuel moisture is about right. If the stick bends or cracks with a dull thud in only one place, the fuel is too wet. (Judgment must be applied in using this technique, because considerable variation can be expected between sticks of differing size and age.)

Greenup—As you walk the site, if you see greenup in the bunch grasses (more than 4 inches tall), forbs, and shrubs, you may have missed your best opportunity to burn in the spring or early summer in this type. Some low-growing evergreen woody shrubs such as kinnikinnick and Oregon grape tend to retard fire spread and reduce flame lengths. It is also desirable to understory burn prior to bud burst in the spring or after the dormant period in the fall to avoid damage to conifers during their more sensitive growing period.

Crown closure—Pay particular attention to canopy crown closure. Canopy closures of more than 60 percent may preclude successful understory burning because of lack of sunlight to dry fuels. A prefire treatment, such as selective cutting of trees, can open the stand and facilitate burning.

Duff moisture—As a rule of thumb, 1 inch of duff is equal to about 10 tons of fuel per acre. Fire may completely consume duff when fuel moisture is less than 35 to 40 percent. Therefore the lower half of the duff should contain at least 40 percent moisture to retain some duff and protect the shallow soils on these sites. Many successful understory burns in this forest type occur when moisture in the lower half of the duff exceeds 100 percent.

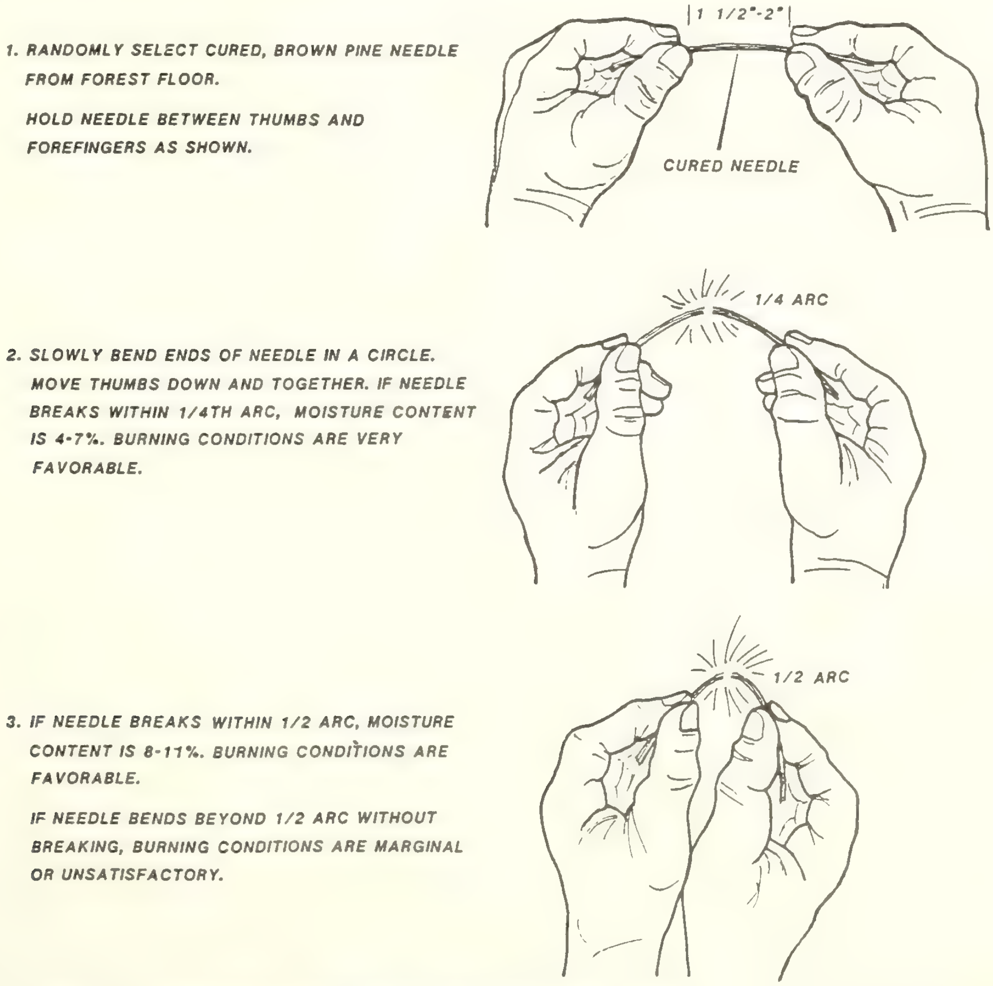


Figure 9—Using a cured ponderosa pine needle to determine moisture content of fine fuels.

WEATHER FACTORS

Fire specialists generally reported that statistical weather data from the past has not been of much help in developing successful understory burning programs in this type. This is true largely because we lack historical information for the spring and fall seasons when the best opportunity exists for burning, and hence most of the RXWTHR and RXBURN runs (Bradshaw and Fischer 1981) can only be based on fire season data. Some fire specialists thought that these programs underestimated acceptable days on the burn site due to location of the weather station.

Greater emphasis needs to be given to taking and storing weather data before and during prescribed burns for use by future managers. At the present time, several of the Districts have RAWS stations on their units. If procedures are implemented to store RAWS weather data, it will provide an excellent source of future information. The majority of those interviewed were using RAWS data to tell them when they were getting close to the planned prescription parameters, thus allowing less travel and expense to check conditions on burn units in the field.

The majority of burners use knowledge of local weather patterns based on past experience or obtained from other local sources, such as ranchers, permittees, contractors, or timber sale purchasers. Valuable climatic summaries are also available for several sites in the Northern Rockies—the Selway-Bitterroot Wilderness and Glacier National Park in particular (Finklin 1983, 1986). Regardless of how weather data are gathered or used, there is a need to improve weather predictions for the two burning periods following the understory burn. Accurate forecasting would allow more cost effective planning of the following 2 days' burns and enable experienced prescribed burners to reduce costly mopup and to prevent escape of prescribed fires.

The following are some general rules of thumb relating to weather that may apply to understory burning in this type:

–Maximum cloud cover should not exceed 30 percent; less is preferred.

–Light showers of less than 0.1 inch generally have little impact and then only for 1-day periods. Heavier rains will retard understory burning for 2 to 3 days unless rain is followed by sunny weather with strong winds.

–Wind is needed on most complex understory burns and particularly units on flat ground to encourage heat dissipation and reduce scorch height. (Complex burns are those where resource values are so high adjacent to the planned burn that you cannot afford to lose even an acre. Examples are private land, thinning areas, campgrounds, or particularly hazardous fuels. Most aerial ignitions are also considered complex because of the safety of the personnel working with the aircraft.) Eye-level winds within the stand of 3 to 10 mi/h are preferred by most prescribed burners and may exceed this at times if control or aerial ignition is not a problem. Aerial ignition becomes unsafe for the helicopter and crew when winds are erratic or more than 15 mi/h. This is true because the pilot must fly particular ignition patterns which can accentuate the effect of wind changes in steep topography. The majority of those interviewed would prefer the wind upslope and in one direction only during the course of the burn. On steep slopes (in excess of 40 percent), winds are not as critical unless they are strong and erratic.

Table 3 displays a range of prescription parameters presently being used for successful understory burning in the seven vegetation types listed.

TIMING

The pine/larch/fir type offers many more opportunities for understory burning than some of the other less fire-tolerant types in the Intermountain West. Because it is adapted to fire at frequent intervals, pine/larch/fir lends itself to prescribed fires in spring, early summer, and fall. Generally summer fires are not needed in this type to accomplish typical land management objectives. Such burns would tend to be costly and may result in excessive scorch and mortality plus loss of duff on many fragile sites. (Summer burns in wilderness units might be appropriate under certain conditions.)

In table 3, we purposely omitted early summer burning because of greenup problems, referred to earlier. In some areas, however, spring burning conditions occur in May or June due to elevation and snowmelt. Generally hot summer burns would remove 100 percent of the duff in this type and could lead to major erosion and/or soil problems, depending on the particular soils and slopes involved. (There may be situations during cool, cloudy periods in late summer in some areas where low-intensity burning can accomplish objectives, but these would seem to be exceptions requiring great care until more experience is gained.)

Under normal conditions, understory burns in this type can be scheduled during the day to meet management needs or early evening to reduce risk of escape. In R-1, most burners interviewed preferred ignition in the spring, early afternoon (1200 to 1500 hours) when weather and/or fuel conditions are at the higher end of the prescription. Favorable conditions often occur only for short periods, such as from 1400 to 1700. You must be prepared to take advantage of these conditions whenever they occur. Two southern Montana Districts burn from 1000 to 1300 or 1600. In complex spring understory burns that include activity fuels, the ignition time may be delayed until 1600 and continued on into the late evening (2200) to complete the unit. The majority of such units are located on south, southwest, or southeast aspects. North, northeast, or east aspects are usually burned in the fall, and ignitions begin from 1200 to 2000, depending on weather, fuel moisture, and loading of natural and activity fuels. Minor amounts of precipitation and low sun angle for subsequent drying of forest fuels sometimes are problems in late fall burning.

Fire specialists in R-6 appear to have a greater number of acceptable burn days than their counterparts in R-1 due to more favorable local weather patterns in which prescribed burn parameters can be met. In addition, R-6 specialists use flame lengths and scorch heights rather than weather and fuel moisture parameters to determine acceptable prescriptions. They are also able to burn more acreage because R-6 has a higher percentage of Forests and Districts in pure ponderosa pine and pine-associated types, and thus more easy-to-burn pine fuels and more stands needing understory burning. Therefore R-6 targets

Table 3—Range of fuel and weather prescription parameters presently used for spring and fall understory burning in pine/larch/fir and associated species; PIPO = ponderosa pine; LPP = lodgepole pine; SP = spring; F = fall

Vegetation type	Fuel moisture 1-h	10-h	100-h	Preferred (acceptable) range: Midflame windspeed	Relative humidity	Temperature	Season	Best firing pattern	Comments
	- - - - *Percent*	- - - -		*Mi/h*	*Percent*	*°F*			
PIPO with grass	6-14	8-18	15-40	5-10 (0-15)	25-35 (20-50)	60-70 (50-80)	Sp, F	Backing fire–strip-head fire ignition	If thinning, burn in spring to prevent total duff consumption.
PIPO with brush	6-14	8-16	15-30	5-10 (0-15)	25-35 (20-50)	60-70 (50-80)	Sp, F	Backing fire–strip-head fire ignition	Same as above; seral browse shrubs respond well to moderate fire intensity.
PIPO with grand or white fir/Douglas-fir	6-14	8-15	15-30	3-8 (0-15)	25-35 (20-50)	60-70 (50-80)	Sp, F	Backing fire–strip-head fire ignition	Fir is very susceptible to fire damage and rot following understory burning.
PIPO with Douglas-fir/bitterbrush	6-14	8-15	15-30	5-8 (3-12)	25-35 (18-40)	55-65 (50-75)	Sp, F	Backing fire–strip-head fire ignition	Bitterbrush resins and dead wood can push fire intensities higher than predicted
PIPO with Douglas-fir/larch (LPP)	6-14	8-15	15-30	6-10 (0-15)	25-35 (20-50)	65-75 (60-85)	F	Backing fire–strip-head fire ignition	Only fall burns— fine fuels lacking for spring burns.
Grand or white fir/incense-cedar/PIPO	6-14	8-15	15-30	6-12 (3-15)	25-35 (20-50)	65-75 (50-80)	Sp, F	Backing fire–strip-head fire ignition	Hard to burn in spring due to fir needle "mat". In fall, expect mortality in small fir. Patches of PIPO can be burned in spring to reduce intensity of fall burning.
Mixed conifer with PIPO (north slopes)	7-14	8-16	15-30	3-7 (0-10)	30-40 (25-50)	60-70 (55-75)	F	Backing fire–strip-head fire ignition	Fuel concentrations and loading may be heavy. Fall burns only due to aspect and mixed conifer type.

are larger than R-1 targets because there is more opportunity for burning. Despite this naturally favorable situation, some R-6 Forests such as the Fremont and Ochoco have excellent understory burning programs (the Fremont program has doubled in size from 10,000 to nearly 20,000 acres per year), while other forests in R-6 are just starting to use understory burning in this type.

Most burners in R-6 preferred spring burning on the south, southwest, and southeast aspects, and most preferred early afternoon ignitions (1200 to 1500). On complex, higher risk units, some burners delay ignition until after 1500 when temperatures usually fall. Although favorable for burning at 0900, weather might go out of prescription on the high side by 1000 or 1100. Waiting until 1500 can also result in conditions too moist for effective burning after 1600 or 1700, a concern on some larger units. Only one District burned in the summer; the ignition period was from about 1500 until 0200 in the morning. Burning at this season of the year when resources may be committed to wildfire suppression may be more risky than burning in spring or fall. Several fall understory burns on north and east aspects have been ignited from 1000 to 1800 with good success.

In addition, R-6 does some "jackpot" burning in the fall in areas of heavy fuel accumulations. This type of burning is completed in the afternoon, from 1200 to 2000. Individual jackpots of large-diameter fuels are ignited and fire is allowed to creep. This reduces the fire intensity at a later time when the understory is burned. This two-stage process can be applied elsewhere where fuel buildup and/or predicted fire intensity are too great for a single burn. We emphasize that this ignition strategy should be used only in the late fall when conditions are not suitable for a complete understory burn.

If smoke pollution is not a serious problem, night burning is an alternative. Night burning in the fall has some advantages in complex units with heavy fuel loadings. Flame lengths and fire intensities are much easier to control. Night burning requires extreme emphasis on safety, and such factors must be included in the planning stage and in on-site briefings prior to the burn. One burner cautioned that those involved in night burning need to be particularly aware of the potential for increased levels of carbon monoxide (CO) close to the flames at night, when fuel consumption and fire intensities tend to be less. Such levels of CO affect one's ability to think, to be patient, and to be observant. The burner suggested that when night burning, personnel should take a break away from the fire to dilute the possible impacts of CO.

TECHNIQUES TO MEET PRESCRIPTIONS

Successful understory burning involves both art and science. Indians used fire in the Intermountain West along their travel routes for hunting purposes and to keep the forest open (Gruell and others 1985). We have since gained considerable knowledge and expertise in this type of burning, enabling us to predict results fairly accurately. Nevertheless, the techniques used to conduct a successful burn are still more art than science and require both formal and on-the-job training. Hands-on experience as well as technical training and theoretical understanding of fuels, weather, and fire behavior are required. Safe and effective understory burning will always be a real challenge to field personnel.

Preburn Preparation

PLANNING AND UNIT LAYOUT

The burners interviewed stressed that understory burning requires a thorough unit layout. Fire, timber, and wildlife specialists, and perhaps others must work together during the planning and field layout phase of the project. It is desirable to lay out units that can be treated during a single burning period and to use natural barriers for firelines where possible. Blocks less than 40 acres are not cost efficient. Many experienced prescribed burners interviewed preferred unit sizes from 60 to 400 acres, with an average size of about 200 acres. Even larger units are possible with aerial ignition. Regardless of size, fire specialists noted that if ignition is not completed within a

single burning period, you must have natural or constructed firelines within the unit to stop the spread and ignition of fuels when conditions are out of prescription. All firelines must be at least the minimum needed for controlling, containing, or confining the prescribed fire to a designated area. If the prescribed burn boss did not prepare the burn plan, he should be given the opportunity to review it at least 30 days prior to ignition. In complex understory burns, it is advisable to have the burn boss prepare the burn plan. In any event, both R-1 and R-6 prescribed burners felt it was important for the burn boss and ignition boss to walk through the burn unit ahead of time.

FIRELINES

Fire specialists from various Districts reported differences in fireline preparation techniques and standards. In the steeper terrain of R-1, natural barriers such as avalanche chutes, creeks, and snow, or existing human-made barriers, like roads, are used wherever possible to avoid building lines. In spring, nonburnable north slopes can serve as firelines. When natural barriers are not available in the West Fork District (R-1), lines are scratched in or black lines are burned in prior to the planned ignition time. On other Districts, to avoid wide lines some lines are put in by small tractors with brush blades. In some cases, water carried by hose is needed to reduce the heat concentrations near the line. Where hand-built lines are needed, one District has the timber purchaser put them in. Some specialists have blasted line for spring burns (Noste and Barney in press). The Superior District (R-1) spent $33 to $46/chain (20 m) to blast fireline in light fuels prior to spring understory burning. In somewhat heavier fuels, others reported hand-line costs of $22 to $30/chain for 9 miles of line as compared to $61/chain for blasted line.

In the flatter terrain of these forest types in R-6, fire specialists on the Bly District of the Fremont National Forest use some 8,000 miles of roads as breaks. Other Districts use foot trails, skid trails, and cow paths along fences as breaks. Some reported using such natural breaks as rims, gaps, and natural rocky outcrops to supplement moist areas such as north slopes, creeks, and wet meadow edges. Only after using all natural and manufactured barriers possible did these prescribed burners put in new lines, often using vehicles such as rubber-tired garden tractors or small tractors with a brush rake, vehicles not possible to use on steeper country. In the fall on the Lakeview District (R-6), burners put in 2-foot-wide lines using wheeled tractors, something they found unnecessary in spring. Few Districts in R-6 find it necessary to use pumper trucks or waterhose for spring understory burning—a major cost savings.

PROTECTION OF LEAVE TREES

Those who burn in the pine-larch-fir type should be able to assure that 90 percent of the leave trees in logged units will survive the fire (fig. 10). This is not possible in heavy total fuel loadings (≥50 tons/acre) or fuel loadings of 15 tons/acre of less than 3-inch fuels unless fire and timber preparation personnel work closely together in designing the burn unit, marking acceptable leave trees, and controlling fuel loading (table 2). The prescribed burners interviewed felt very strongly about the following ideas concerning leave trees in understory burning:

1. Size and spacing of leave trees become critical when activity fuels exceed 30 tons/acre. Prescribed burners consider the following diameters as minimum for the species shown. The numbers of trees per acre are considered the maximum desirable preburn total of all species that will allow heat and smoke to escape without undue crown scorch.

Species	Minimum diameter	Maximum number/acre preburn
	Inches	
Douglas-fir	16	30
Western larch	12	40
Ponderosa pine	12	40
Grand (or white) fir	20	30

(Note that if a stand has both Douglas-fir and western larch, the maximum total number per acre of both species would be 30, not 70. Obviously, "natural" understory burning for wildlife and hazard reduction purposes is often done with greater than 100 trees per acre.)

2. Leave trees need special protection when total fuel loading exceeds 30 tons/acre and when less-than-3-inch diameter fuels exceed 10 tons/acre. This is true except when all leave trees are 20 inches d.b.h. or more and there are adequate holes in the canopy for heat and smoke to escape. If protection is needed, fuels should be removed from at least 6 feet around the bole of the tree. Special care should be taken not to place fuels on the downhill side of trees. This could lead to additional intensity, that with normal updraft could scorch crowns. Several Districts reported that they removed all fuels within 25 feet of superior seed trees.

3. Fire specialists reported that fuel treatment or manipulation is needed under the following situations:

–*Ladder fuels close to leave trees.* Reduce ladder fuels to a low profile (2 feet or less). The tops should not fall close to the downhill side of an adjacent leave tree.

–*Natural fuels or slash concentrated near bole of leave tree.* Pull back slash or natural fuels 6 to 8 feet, as needed, to reduce fire intensity near the bole and live crown. This should be done as a planned treatment and not as an afterthought the day the unit is ignited. Do not throw slash on the lower side of the leave tree. Some Districts in R-6 move large logs to reduce fire intensity and protect the leave trees. Some Districts open units for firewood cutting to help reduce large fuels (Gruell and others 1985).

–*Slash depths exceed 2 feet under crowns of leave trees* (this may include precommercial thinnings). Prescription windows can be widened by reducing the slash depth to 2 feet or less by lopping, walking it down and compacting with a dozer, or allowing the winter snowpack to compress it. In precommercial thinned areas, prior to understory burning, some R-6 forests found it necessary to yard large logs into small clearings. Other burners allow extra aging of slash and settling of fuel beds (2 to 5 years) to reduce fuel bed depth and thereby flame length and fire intensity.

–*Predicted fuel loadings are greater than 35 tons/acre and will result in flame lengths that would cause excessive scorch damage.* In activity fuels, your slash plan should specify tree length yarding or yarding tops of certain

Figure 10—Fall understory burn using a strip-head fire to protect leave trees in a ponderosa pine/ larch/fir stand following logging. Fuel loading averages 36 tons/acre. Fall burning is needed to prepare the site for natural regeneration.

species to reduce less-than-3-inch diameter fuels to an acceptable loading. Limbing should be done at the landing rather than in the woods. In natural fuels, schedule two understory burns, or a jackpot burn of heavier fuels followed by broadcast understory burning of lighter fuels.

OTHER ONSITE FUEL TREATMENT

Although most burners expressed concern for reducing fuels to protect leave trees, at least one District indicated that occasionally there is also need to leave enough fuels to burn the understory. For example whole tree yarding may result in not enough fuels left in the woods to carry the fire. On another District lopping not only held down flame length—which protects leave trees—but also produced a more continuous fuelbed that facilitated understory burning in the mixed conifer forests. A third District lopped in the fall for esthetic reasons as well as to achieve more uniform fuels for understory burning the following spring. One District fire-proofed some down logs (larger than 6-inch diameter) by pulling fuels away to provide woody material (10-15 tons/acre) for nitrogen-fixing microbes (Harvey and others 1979a, 1979b; Jurgensen and others 1979).

Both R-1 and R-6 leave snags wherever possible, except where hazardous to the logging contractor or the prescribed burning crews or to prevent escape of the burn. (See Regional and Forest snag guidelines for additional information.) Region 6 shows great concern to save snags, either by pulling away materials from the base of the trees, hand-lining them, or by using low-intensity understory burns and conscientious ignition crews to save them. In other instances, they simply understory burn beneath 12- to 24-inch trees, some of which become replacement snags.

Several fire specialists indicated it may be necessary to protect highly desirable snags within the interior of a burn unit. This may require firelines around the base of a snag or a modified ignition pattern adjacent to the snag. Because they are easily ignited by firebrands, it is extremely difficult to protect soft snags if flame lengths of more than 3 feet are predicted. Many prescribed burners advise that to facilitate control, soft (partially rotten) snags within 100 feet of the upwind side of the burn perimeter should be dropped prior to the ignition of the unit.

BRIEFING AT THE BURN SITE

The burn boss must thoroughly brief all personnel on site to ensure that assigned duties and safety—including hazardous situations and escape routes—are understood prior to the ignition of the unit. It is extremely important that the burn boss cover fuels data, present and predicted weather, ignition methods, and the expected fire behavior. Terminology needs to be reviewed with all crews so that,

for example, everyone uses the terms "torching" or "crowning" properly. The burn boss should ensure that communications, suppression and firing equipment, and personnel are adequate to complete the planned burn. It is advisable to have good quality maps and large aerial photos (8- by 10-inch if possible) of the unit, with overlays showing the planned ignition pattern to be used. When weather and fuels conditions warrant, the prescribed burn boss should alter the ignition plan as needed to safely burn the unit.

Before breaking up into ignition and holding crews, personnel should be given the opportunity to ask questions. Following the general briefing, the ignition boss and holding boss will review the procedures and tactics to ignite and control the planned prescribed fire. Remember, after duties are assigned, it is still the burn boss's decision whether to burn or not. The ignition boss must tell his firing crews not to begin ignition until given the final word. If uncertain, with approval of the burn boss, a test fire can be built in a place where it can be immediately put out if flame lengths and scorch heights exceed prescription. The burn boss is responsible for the entire burn until relieved by the prescribed fire manager or unit manager. This might include mopup and suppression as required.

Ignition Strategy To Meet Objectives

Prescribed burners unanimously agreed that ***patience*** is the key to successful ignition in understory burning:

1. You must wait until you are in prescription before you ignite.
2. When using strip head fires, you must let one strip die down before you start another; "patience" means not too fast ***and*** not too slow.
3. You must avoid getting strips too wide; this can start to happen when ignition crews are in a hurry to finish.
4. You must use "torch finesse," meaning tip your torch back up at the right time, ***light and look back*** at the last strip, and observe fire behavior. (Determine if the strip you just lit fits into the total ignition plan.)
5. You must continually observe flame length. Flame length is a good indicator of fire intensity and it may vary greatly with strip width, rate of ignition, and how the previous strip reacts to the one you are lighting. If the flame length is too great, narrow your strips; if too little, widen strips slightly.
6. Small ignition crews of two to eight persons are usually better than large crews for this type of burning. You must avoid the temptation to speed up the burning by adding to the crew.

Ordinarily, the prescribed burn boss should be located in a spot where he or she can observe the total burn and be in radio communication with the ignition boss and holding boss. On some Districts burners thought that each person should have a radio, to allow instant and direct communications during ignition. As a minimum, ***at least every other person should have a radio.*** The ignition boss needs to know the experience, stamina, and patience of ***each member of the firing crew.***

The ignition boss must understand how the rate and width of ignition strips will affect flame lengths and fire intensity. The burn boss also monitors fire intensity to ensure that a convection column does not develop in an understory burn. Experienced burners disagree on whether or not the burn boss should carry a torch. Most believe the burn boss should ***not*** carry the torch, but instead observe and if necessary control seasonal and less experienced torchusers and thus give overall guidance to the burn. On less complex burns, however, the burn boss might carry a drip torch, but only if all personnel are experienced.

If conditions warrant, the ignition boss may request permission from the prescribed burn boss to shift personnel from the holding crew to the ignition crew or alternate positions each day. As a general rule, once the backfire is burned out, only two to three personnel are used for holding crews. In many of the early spring or late fall burns, no holding crews are needed once the backfire is secured. On less complex understory burns, the burn boss may also be the ignition and holding boss. Use only the personnel and equipment needed on site to burn the unit in a safe and cost-efficient manner. There should not be excess personnel standing around without an assignment.

IGNITION TECHNIQUES AND FIRING PATTERNS

Districts and units that have developed good understory burning programs realize the importance of selecting the best ignition pattern for the situation that exists on the burn site. This requires good knowledge of fuel conditions on site and how weather factors and topography will influence the pattern selected. All those interviewed agreed that ignition patterns and rate of ignition directly affect flame length and fireline intensity. An experienced ignition boss knows how to keep flame lengths within prescription by adjusting strip width and speeding up or slowing down the rate of ignition. This requires good radio communication with each member of the ignition crew. The following ignition techniques and/or firing patterns are presently being used in the Intermountain West for understory burning in pine/larch/fir types. The choice of pattern depends on topography and wind conditions.

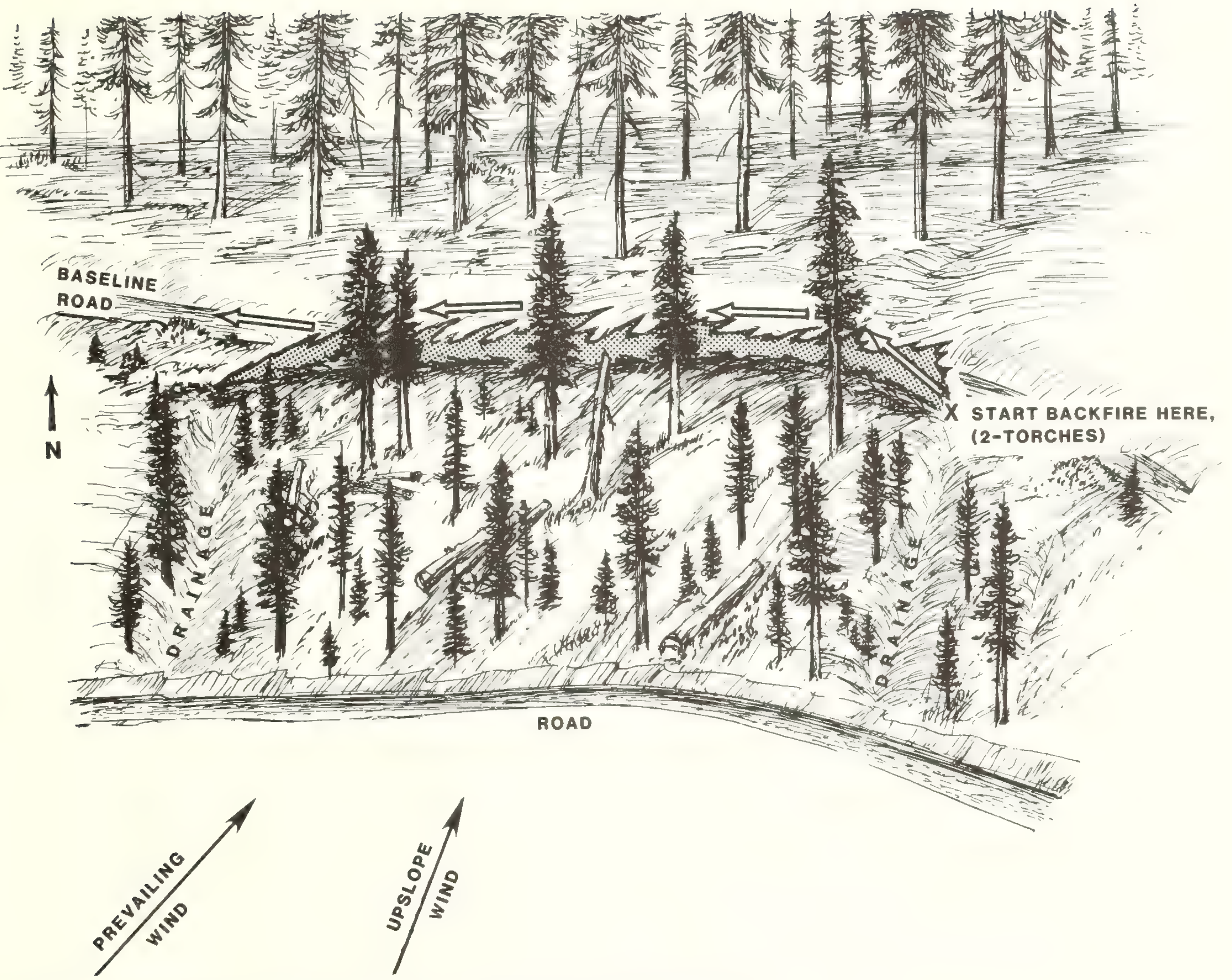


Figure 11—**Backing fire**: Excellent method for the initial firing of most understory burns. Generally not practical in the Intermountain West for burning the complete unit.

Backing Fire—The fire is ignited adjacent to the leeward base line as shown in figure 11 and allowed to back into the wind for at least 1 to 2 chains (66 feet). Backing fires normally spread slowly (less than 1 foot/minute) so about 30 minutes to 1 hour should be planned to anchor the unit. Backing fires are generally used in this forest type for anchoring the uphill or downwind side of the burn unit. In most cases the fire will be anchored to natural barriers such as a snow line or to roads and trails. Light-impact machine or hand lines will also be used where needed.

Experienced burners reported that in most cases backing fires are not practical for burning the complete unit in the Intermountain West. Some of the reasons given were as follows:

1. It takes so much time to complete a burn that internal lines have to be built within the burn unit to stop or control fires. This increases per acre costs. Backing fires may consume more fuel (including duff) than strip head fires.

2. In the spring and late fall, the fine fuel, duff, and soil moisture prevent continued spread of the fire.

3. A backing fire requires a strong steady wind to burn effectively; this seldom occurs for more than a single burning period.

4. On large units that require several days to burn with a backing fire, changes in weather would increase chances of escape.

5. Backing fires are not practical on steep slopes (>40 percent). Even when internal lines are built, burning materials will be constantly rolling and starting fires downhill. Such ignitions will develop into point source head fires that can produce excessive flame length and crown scorch in this type. Even on less steep slopes, burning snags may fall or roll across fire lines, again leading to head fires.

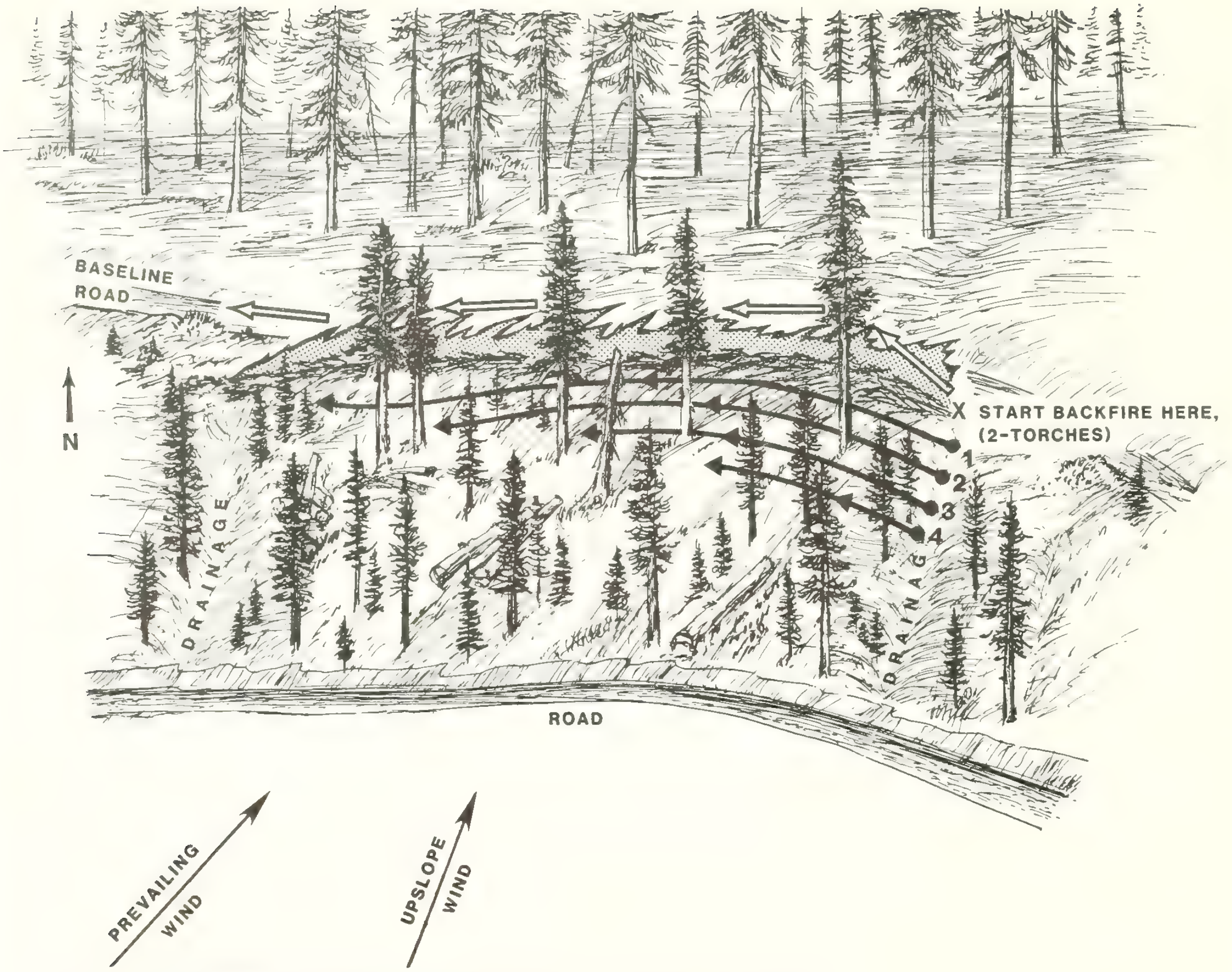


Figure 12—**Strip-head fire**: Excellent ignition method for light fuel loads of 5 to 15 tons/acre. Most effective when each torch person has radio communication with the ignition boss. This ensures the strip width can be changed at any time to control the fire intensity.

Strip-Head Fire—This ignition technique (figs. 12 and 13) calls for setting a series of lines of fire, starting at the upwind edge of the firebreak. The lines of fire must be ignited in such a way that each strip-head fire will result in flame lengths and fire intensity within the prescription parameters. The strips may vary in width from 10 feet to 100 feet. Some burners will initially try for 20-foot strips, but will extend them to 30 or 40 feet if the leave trees can handle the resulting flame lengths. But they stress that the resulting ***flame length is the prime criteria—not strip width***. Widths must be adjusted constantly for changes in stand density, size of leave trees, fuel quantity, fuel arrangement, and weather conditions on site. Shifts in wind direction can be adjusted for by slight changes in the angle of strip fires with respect to the baseline or burned out portion of the unit. It is important to check flame lengths where the strip-head fire from the strip just ignited meets the backing fire of the previous strip. This will be the hottest area and will have the greatest fire intensity and scorch heights. Patience is needed to keep the fire intensity within prescription at this point. There will be concentrations of fuel in most understory burns where flame lengths and scorch heights will exceed those predicted for short durations. This should be expected and is not a reason to delay burning.

The strip-head fire is the most widespread ignition method used in the Intermountain West for understory burning. This firing method permits the burner to ignite the unit in a timely manner, with optimum conditions for control of fire intensity, rates of ignition, and smoke dispersal. In most cases, the unit can be treated during a single burning period, making control easier and yielding lower unit costs per acre.

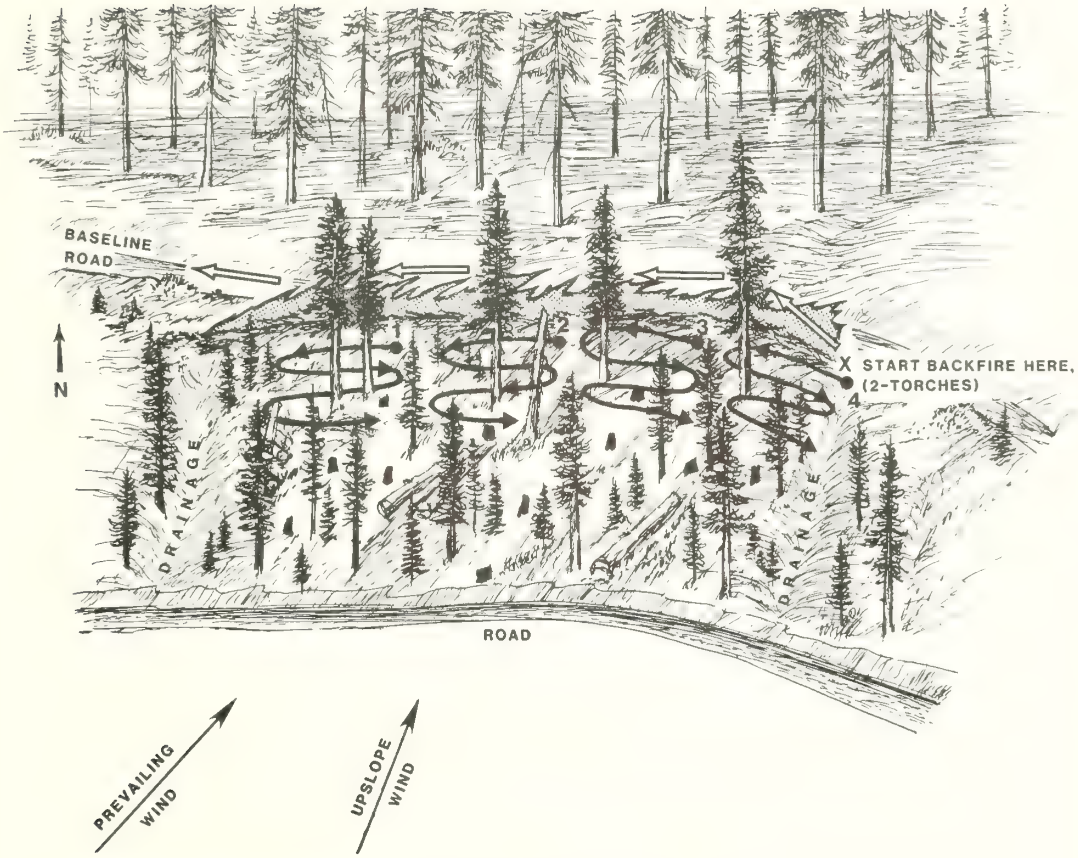


Figure 13—**Modified strip-head fire**: Best of the two strip-head fire ignition methods when understory burning in moderate-to-heavy fuel loadings of 15 to 50 tons/acre. Radio communications with all torch persons essential when burning in these fuel loadings.

Flanking Fire—This ignition technique (see fig. 14) may have application in the pine/larch/fir type if the 1-hour fuel loadings are less than 2 tons/acre. It is used to supplement other ignition methods and requires three or more of the ignition crew working into the wind setting fires. The fires spread out in a V-shape behind the torchusers. Both fires then spread into the wind and to the sides—toward each other, resulting in the term "flanking." ***If used alone under dry conditions***, this ignition technique has little chance of success in reaching understory burning objectives. The following are some points to consider before using this method:

1. A flanking fire can only be used if there are no adverse wind shifts.
2. Total 1-hour fuel loading is less than 2 tons/acre.
3. The base line must be secure prior to ignition into the wind.
4. On the dry side of the prescription, this ignition technique usually results in higher intensities than other methods, with little control over the rate of ignition and/or scorch height.
5. Using this ***firing method alone*** requires more knowledge of fire behavior and more experience with unusual fire behavior situations than most prescribed burners have at present.
6. This firing method may be useful for securing flanks of a unit that you intend to burn with a backing fire or strip-head fire.

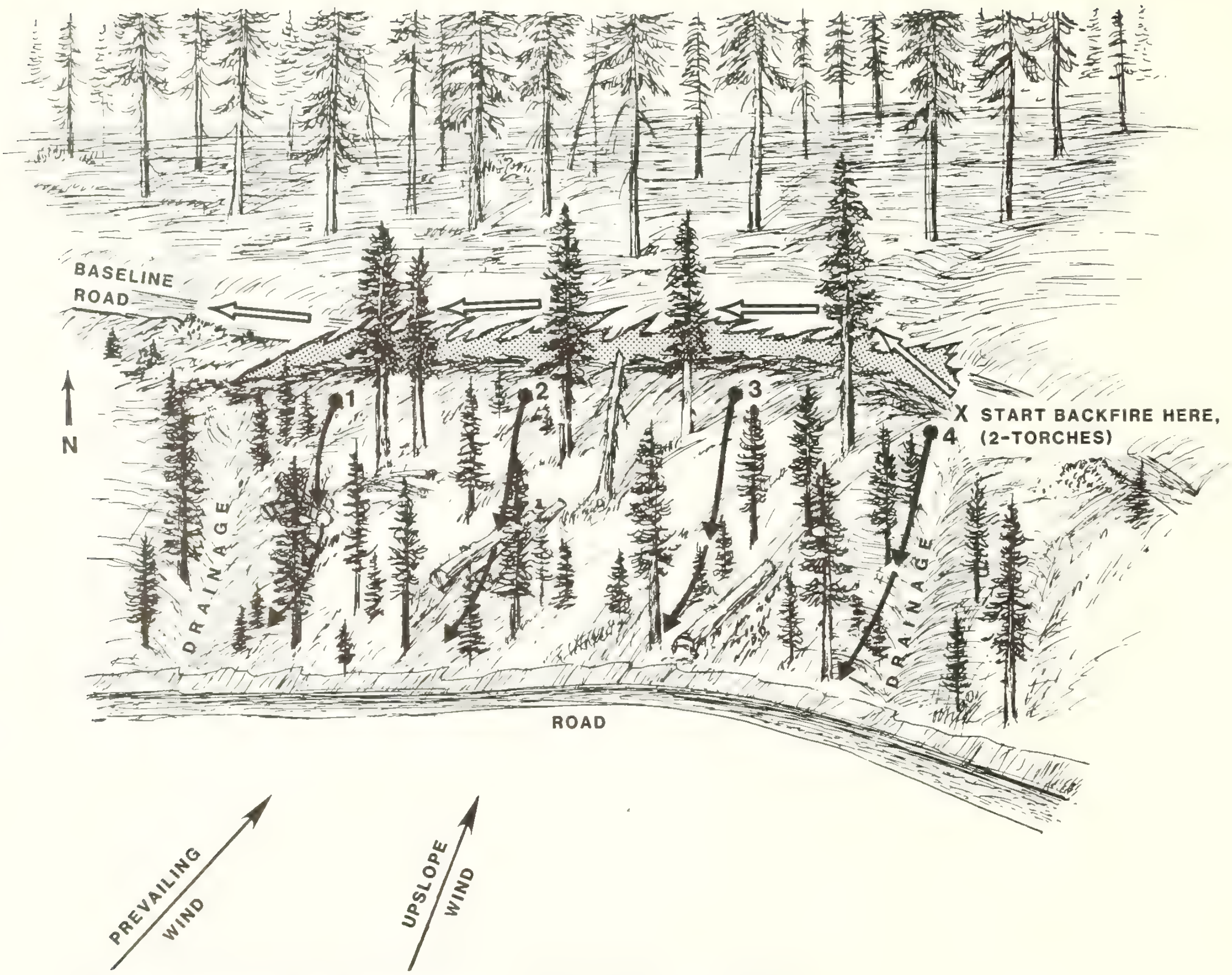


Figure 14—**Flanking fire**: Has best application in this type when the 1-hour fuel loading is less than 2 tons/acre.

Spot-Head Fire—This ignition method involves setting a series of small spot fires, which spread in all directions as they burn together (fig. 15). Generally these spot fires burn together similar to a series of strip-head fires except that you have little control once several lines of spots are burning. Several burners thought that this method creates hot spots, which can lead to an excessive number of large fire whirls, especially with unstable weather conditions. This would result in flame lengths and scorch heights unacceptable for understory burning.

Region 6 is using a modified version of this method along with jackpot burning in the late fall. They wait until the fine fuels are damp and then ignite jackpots of large fuels as they proceed through the unit. The weather and fuel moisture prevent the spots from burning together. This modified spot-head fire pattern is considered as preparation for an understory burn in the future. One District burns large logs on 25 percent of an area and then returns the following season to understory burn. This method has practical applications in the pine/larch/fir type, but it should be used with caution. This procedure should not be attempted during the late summer or early fall, because unburned islands of fuels will dry out, causing a reburn and unacceptable damage to the stand. The following requirements should be considered before using this ignition method:

1. Proper timing is critical. Don't program fall jackpot burns until you have completed understory burning in less heavy fuels and until weather conditions are too moist for normal understory burning.
2. Fuel loading may be high where fuels are concentrated but should be light to moderate in the majority of the burn unit.
3. Do not attempt this procedure unless you are fully qualified in understory burning and know the weather patterns in the area.
4. This method works best where the majority of trees are 16 inches diameter or more, or the stand is open and clumpy.

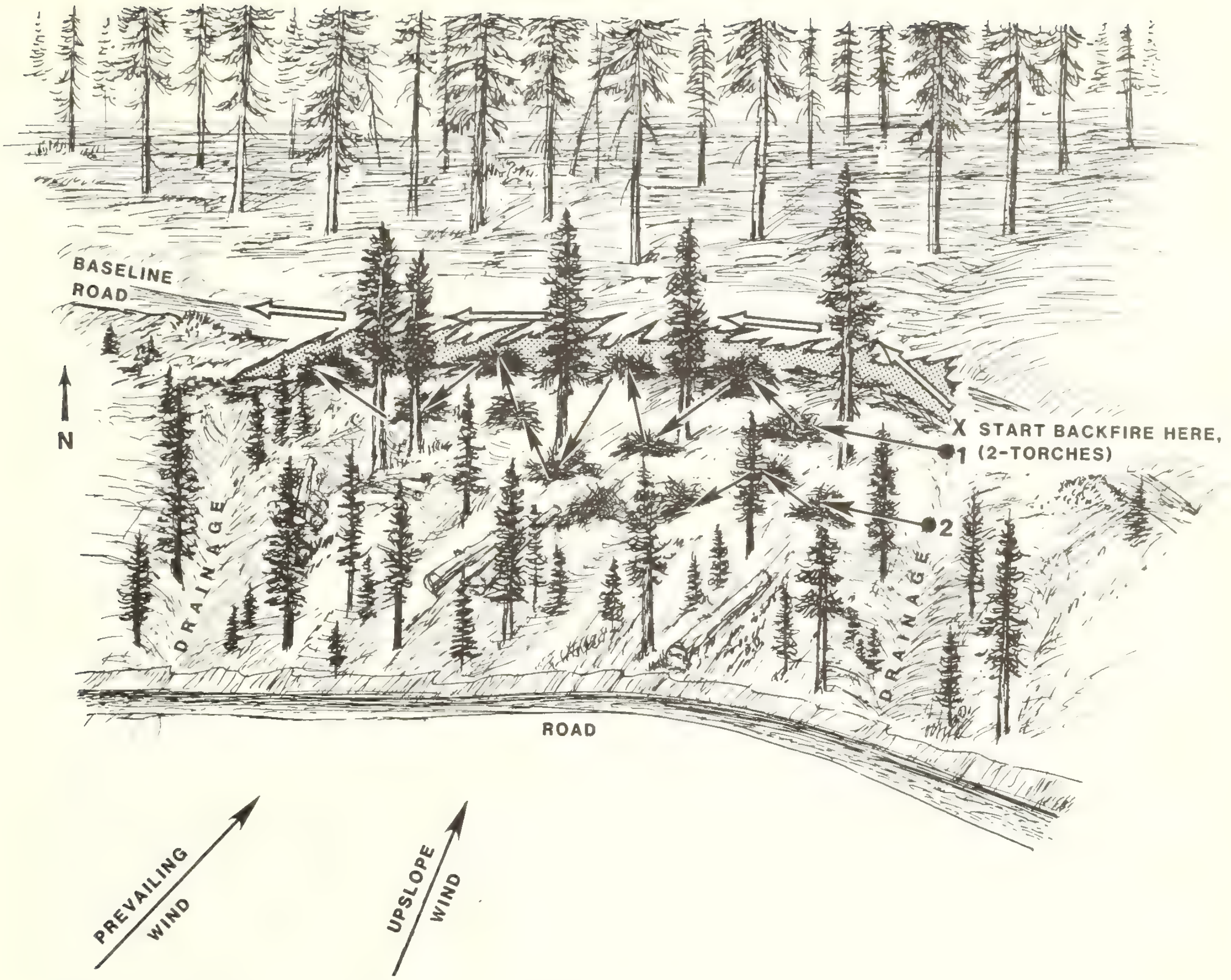


Figure 15—**Spot-head fire**: Pattern similar to the strip-head fire, but in this method only small or large slash concentrations are ignited allowing the fire to spread and burn in all directions. Region 6 uses a modified version of this method for jackpot burning in heavy fuel concentrations during the late fall.

TIMING OF IGNITIONS

Techniques relating to timing have already been covered under the section on developing successful prescriptions. Experienced burners note that the decision about whether to burn in spring or fall is important in that cost may vary from a low of $2/acre in spring, to more than $200/acre in fall on north slopes where mineral soil is needed for regeneration purposes and mopup may be needed. Spring burning has the best cost/benefit ratio, assuming that objectives can be met.

FIRING EQUIPMENT AND TECHNIQUES

The majority of fire specialists interviewed prefer the standard drip torch for most understory burning in pine/larch/fir (see advantages in table 4). The hand-held drip torch using a 70/30 diesel/gas mixture is an excellent tool for burning in this type. Supplying fuel to the firing crew may be a problem. A common method is to place 5-gallon containers at selected locations in or adjacent to the burn. This usually means carrying 5-gallon containers up and across steep slopes. The Fremont and Wallowa-Whitman National Forests in R-6 have modified three-wheeled ATV's to pack fuel to ignition crews (fig. 16). They also ignite units with a modified drip torch mounted on the three-wheeler. Four-wheeled ATV's work even better because they are more stable than the three-wheelers. This appears to be a good method on slopes less than 35 percent and where stands are open enough to permit such vehicles to operate. Other ignition methods include propane torches and aerial ignition devices (table 4).

Table 4—Common ignition methods for understory burning

Method	Fuel mix or type	Where used	How used	Advantages	Disadvantages
Drip torch	70% diesel. 30% regular gas.	All understory burns.	Ignition crew walks through fuels, setting a line or continuous series of spot fires.	A fast lightweight system—versatile, easy to use, little maintenance.	Holds only 6 quarts. Safe, fast, fuel resupply a problem.
Modified ATV drip torch	Same.	In open-grown stands <35% slope.	Operator on ATV lights strips of fire.	Fast, avoids fatigue, saves time. Can resupply fuel to firing crew as needed.	Limited to slopes <35%, can't operate in dense stands, heavy fuels, or on rocky terrain.
Backpack propane torch	Commercial liquid propane.	Most understory burns with low fuel moisture.	Ignition crew walks through fuels, setting series of spot fires.	Lasts two to three times longer than drip torch.	Can't light continuous line of fire, is slower and less effective when fuel moisture nears upper limits of prescription.
Fusees	10 minute, commercial manufacture.	Steep slopes in inaccessible areas; good in grass or pine needle litter.	Ignition crew walks through fuels. Must stop to ensure each spot is ignited.	Excellent for steep, inaccessible areas.	Sulfur fumes bad for air quality Slow and thus expensive.
Helitorch	Jellied gasoline. Regular gas and powder mixture. See mix instructions.	In understory burns with light fuel loadings (<15 tons/acre).	Helicopter with torch slung below ship.	Can burn large units very fast, at low costs/acre; several units can be ignited during a single burning period.	Safety cable hang-ups and ignition outside burn unit a problem. Must set helicopter down between foggy strips causing some mechanical problems to ship. Need large crew. Costly for small units. Difficult to mix fuel at low temperatures.
Aerial ignition device (referred to as "aids" dispenser)	Potassium permanganate/and 50% solution ethyleneglycol in plastic ping pong ball.	Most understory burn situations where rate of ignition shows good cost benefits.	Helicopter with Mark III aids dispenser mounted in doorway.	A safe, fast, inexpensive aerial ignition device. Requires only pilot plus operator. Can ignite several units in one burning period. Can be used in areas of high crown density.	If single unit is ignited the helicopter may need to set down between strips. Costs may be high for small single units.

Figure 16—Strip ignition with a modified drip torch mounted on the back of a small ATV works well in R-6 on slopes less than 25 percent.

PERSONNEL

Experienced prescribed burners noted that the quality and experience of each person on the ignition crew is extremely important when burning under standing trees. The ignition boss must have good technical training, must understand practical ignition methods, and must be an experienced supervisor. The ignition boss needs to know and understand the strengths and weaknesses of each member of the ignition crew. When burning heavy fuels, it is particularly important to use experienced people who are able to recognize and avoid hazardous situations.

Understory burning is generally hard work, and the firing crew needs to be in good to excellent physical condition. Aerial ignitions should be considered on steep, rocky terrain, wherever possible, for both safety and cost effectiveness. When new or inexperienced personnel are assigned to the ignition crew, the ignition boss should place them between other experienced personnel. It is important that each member of the ignition crew understand torch finesse or when to tip back the torch. Each member of the firing crew is responsible to stop occasionally, look back, and judge the result of his or her burn pattern. Patience is essential, and the ignition boss must ensure that his or her crew is working together as a team. Although some of the following points have been mentioned earlier, experienced burners agree that they are critical:

1. Each torch person must have a positive attitude toward the job and understand both the objectives and the fire behavior expected prior to actual ignition.
2. Impatient or high-strung personnel should not be used on the ignition crew.
3. In complex burns, the prescribed burn boss and ignition boss will not carry a torch.
4. Personnel must have adequate breaks, as too much carbon monoxide can impair judgment and could lead to a serious safety problem, particularly on night burns.
5. Strips must be kept squared off; do not let ragged edges develop; manage ignition personnel wisely and exchange them among jobs when they become fatigued.
6. Ignition crews should be as small as possible and still meet assigned targets in the time allowed. When understory burning in thinning slash, do not use more than a two-person ignition crew.
7. Flame length should be the major criterion of the burn and should be controlled by varying strip width. If narrow strip widths still produce flame lengths exceeding the prescription, you should not be burning under standing trees.
8. All personnel on the burn unit need good radio communications.

MONITORING/EVALUATION: DATA STORAGE-RETRIEVAL

Reviewing and understanding preburn, during burn, and postburn factors that indicate to what extent you have achieved your objectives and why is important to any burning program (fig. 17). We learn from both our successes and our failures. Intensive monitoring is not necessary for well-established, successful programs, but even experienced burners think that they should evaluate a few burns each year. Newcomers should monitor and evaluate all understory burns (van Wagtendonk and others 1982).

As part of the planning process, data are collected on preburn fuel levels, using either photo guides (Fischer 1981; Maxwell and Ward 1979) or line-intercept, downwoody measurements (Brown 1974). For wildlife and range burning additional data would be needed: shrub cover, grass production, and numbers of trees per acre by d.b.h. and height classes (see also fuel data collection methods in previous section, Fuel Factors).

During the burning season, experienced burners have a variety of methods for determining when moisture and weather conditions are right to achieve objectives (see Prescriptions above).

During the burn itself, the primary measurement is often an estimate of mean flame length, although some prescribed burners estimate rate-of-spread as well and take photographs to document flame lengths. Following the burn, many prescribed burners sample 10 percent of their individual burn units to obtain a measurement of the amount of fuels that remain unburned and the amount of mineral soil exposed by the fire. Successful programs monitor only enough to be sure that they accomplish their objectives. They keep monitoring costs low by sampling only key factors. Wherever possible, they use existing data and sample only for new objectives where the results are not well established from past experience. Monitoring and evaluation demand measurable land management objectives and, in turn, fire effects objectives.

Individuals should be assigned to specific tasks involved with monitoring, just as they are in ignition and holding. This is particularly true during the fire itself, because that is when such tasks are most easily forgotten. Normally the fuels technician, fuels specialist, or the prescribed burn boss would be responsible for most preburn and during burn measurements, although the prescribed burn boss should consider delegating weather measurements during the burn to another person who can give this high priority. Postburn measurements can be made by the fuels

Figure 17—Spring understory burning in natural fuel loadings of 5 to 10 tons/acre, to fireproof and protect a potential high-value recreation site. Shows photopoint installed for evaluating and monitoring flame lengths and intensity.

technician or the appropriate specialist, depending on the objective. Personnel from the benefiting function or discipline are usually responsible for measuring the results of the site-specific objectives: that is, the silviculturist would measure mineral soil exposure; the wildlife or range specialist the impact on wildlife habitat or range improvement; the fire manager the effect in general on trees, shrubs, grasses, and soils; and the forest hydrologist the results in terms of any water problems associated with firelines, erosion, etc.

Monitoring techniques have been discussed by a number of authors (Brown and others 1982; Fischer 1978; Martin and Dell 1978; van Wagtendonk and others 1982). Those most useful in understory burning would seem to include permanent photo points, which can be used for comparisons of before and after burning results; duff pins placed along a transect line to give accurate measurements of duff reduction; ocular estimates of fuels, using a photo guide (Fischer 1981); and weather readings, using fuel sticks, hygrothermographs, or more extensive RAWS weather units or climatronix units available on some Districts. Some Districts may want to consider more sophisticated techniques, using transects, plots, and quantitative inventory techniques (Brown and others 1982; van Wagtendonk and others 1982), but careful consideration must be given to costs and benefits of these measurements.

After the smoke has cleared and you have completed your prescribed burning, the prescribed fire manager or fuels specialist must take time to analyze the effectiveness in meeting objectives as well as the safety and cost effectiveness of the total program. This evaluation is critical if you are to make improvements for the future. The present technology in computer spread sheets should enable the unit manager to keep accurate unit costs for all prescribed burning. This should encourage land managers to pay more attention to unit size when programming understory burning.

It is also important to store understory burning data to assure it can be retrieved for future needs. It may be possible to use a system that silviculture or timber staffs have already set up and that is operational. System 2000, for example, is being used by Forest Service personnel in R-1 and R-6 with good success. Regardless of the system used, it should be easily accessible and should provide valuable information. All prescribed burners need to broaden their experience and be more cost-effective in the future.

CONCLUSIONS

Most experienced burners recommend "Start small and build toward success. Do not pick the toughest burning problem first!" They also say that good programs are usually tied to a positive management attitude toward use of prescribed fire. Other important conclusions and suggestions are as follows:

1. Teach "patience" in training your burning staff.
2. The best success is often achieved with small crews of three to 10 people or fewer. (You have more patience, better control of the ignition crew, and you are more likely to use logical boundaries.)
3. Use natural, existing, or logical boundaries and the time of day/time of year to facilitate control. Natural/logical boundaries will also help hold costs down.
4. Use great caution in trying to understory burn in the pine/larch/fir type when it contains the following species and/or fuel conditions: white fir forests, lodgepole pine, white pine, spruce, cedar-hemlock, areas with mountain-mahogany, north slopes with high fuel loading, and stands needing thinning.
5. Most successful prescriptions have a simple burning plan format, which accomplishes burn objectives in a timely and cost efficient manner.
6. Do not be afraid "not to burn!" if conditions warrant.
7. In writing successful prescriptions, it is important to know the relationship of fuel moisture and fuel consumption to determine the appropriate flame lengths and fire intensities.
8. Wind (or slope) can help hold down scorch height.
9. Carefully study the available preburn preparation suggestions and the variety of ignition techniques and patterns before developing your best plan for a given area and a particular set of objectives.
10. Before ignitions, brief your crews, preferably using large aerial photos, maps, and overlays to ensure good communication between ignition boss and crew.
11. Understory burning requires hard work and careful preparation. It also may require two or three prescribed burns over an extended period of time to meet all the desired objectives.

REFERENCES

Albini, Frank A. Estimating wildfire behavior and effects. General Technical Report INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 92 p.

Anderson, Hal E. Aids to determining fuel models for estimating fire behavior. General Technical Report INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 22 p.

Barrows, J. S. Fire behavior in Northern Rocky Mountain forests. Station Paper 29. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station; 1951. 103 p.

Beaufait, William R. Prescribed fire planning in the Intermountain West. Research Paper INT-26. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1966. 27 p.

Bevins, Collin D. Estimating survival and salvage potential of fire-scarred Douglas-fir. Research Note INT-287. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 8 p.

Biswell, Harold H.; Kallander, Harry R.; Komarek, Roy; Vogl, Richard J.; Weaver, Harold. Ponderosa fire management. Miscellaneous Publication 2. Tallahassee, FL: Tall Timbers Research Station; 1973. 49 p.

Bradshaw, Larry S.; Fischer, William C. A computer system for scheduling fire use. Part I: the system. General Technical Report INT-91. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 63 p.

Brown, James K. Handbook for inventorying downed woody material. General Technical Report INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 24 p.

Brown, James K. A process for designing fire prescription. In: Prescribed fire by aerial ignition: Proceedings of a workshop; 1984 October 29-November 1; Missoula, MT. Missoula, MT: Intermountain Fire Council; 1984: 17-30.

Brown, James K.; Oberheu, Rick D.; Johnston, Cameron M. Handbook for inventorying surface fuels and biomass in the Interior West. General Technical Report INT-129. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 48 p.

Brown, James K.; Marsden, Michael A.; Ryan, Kevin C.; Reinhardt, Elizabeth D. Predicting duff and woody fuel consumed by prescribed fire in the Northern Rocky Mountains. Research Paper INT-337. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 23 p.

Burns, Russell M., tech. comp. Silvicultural systems for the major forest types of the United States. Agriculture Handbook No. 445. Washington, DC: U.S. Department of Agriculture, Forest Service; 1983. 191 p.

Burgan, Robert E. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculator: user's manual. General Technical Report INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 25 p.

Clark, Bob; Roberts, Fred. A belt weather kit accessory for measuring woody fuel moisture. Fire Management Notes. 43(3): 25-26; 1982.

Covington, W. Wallace; Sackett, Stephen S. The effect of a prescribed burn in southwestern ponderosa pine on organic matter and nutrients in woody debris and forest floor. Forest Science. 30(1): 183-192; 1984.

Ferry, Gardner; Abeita, Fernando; Bancroft, Larry; [and others]. Prescribed fire smoke management guide. 420-1. Washington, DC: National Wildfire Coordinating Group, Prescribed Fire and Fire Effects Working Team; 1985. 28 p.

Finklin, Arnold I. Weather and climate of the Selway-Bitterroot Wilderness. Moscow, ID: University of Idaho Press; 1983. 144 p.

Finklin, Arnold I. A climatic handbook for Glacier National Park—with data for Waterton Lakes National Park. General Technical Report INT-204. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 124 p.

Fischer, William C. Planning and evaluating prescribed fires - a standard procedure. General Technical Report INT-43. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978. 19 p.

Fischer, William C. Photo guide for appraising downed woody fuels in Montana forests: interior ponderosa pine, Ponderosa pine—larch—Douglas-fir, larch—Douglas-fir, and interior Douglas-fir types. General Technical Report INT-97. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 133 p.

Gruell, George E.; Bunting, S.; Neuenschwander, L. Influence of fire on curlleaf mountain-mahogany in the Intermountain West. In: Fire effects on wildlife habitat—symposium proceedings; 1984 March 21; Missoula, MT. General Technical Report INT-186. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985: 58-72.

Hall, Frederick C. Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington. R-6 Area Guide 3-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1973. 62 p.

Harrington, Michael G. Preliminary burning prescriptions for ponderosa pine fuel reductions in southeastern Arizona. Research Note RM-402. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 7 p.

Harrington, Michael G. Stand, fuel and potential fire behavior characteristics in an irregular southwestern Arizona ponderosa pine stand. Research Note RM-418. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1982. 6 p.

Harvey, A. E.; Jurgensen, M. F.; Larsen, M. J. Role of forest fuels in the biology and management of soil. General Technical Report INT-65. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979a. 8 p.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. Fire-decay: interactive roles regulating wood accumulation and soil development in the Northern Rocky Mountains. Research Note INT-263. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979b. 3 p.

Jurgensen, M. F.; Larsen, M. J.; Harvey, A. E. Forest soil biology—timber harvesting relationships. General Technical Report INT-69. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 12 p.

Martin, Robert. Prescribed burning techniques to maintain or improve soil productivity. In: Reforestation of skeletal soils: Proceedings of a workshop; 1981 November 17-19; Medford, OR. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1982: 66-70.

Martin, Robert E.; Dell, John D. Planning for prescribed burning in the Inland Northwest. General Technical Report PNW-76. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1978. 67 p.

Maupin, John. Stage underburning in ponderosa pine. Fire Management Notes. 42(3): 16-17; 1981.

Maxwell, Wayne G.; Ward, Franklin R. Photo series for quantifying forest residues in the: Sierra mixed conifer type, Sierra true fir type. General Technical Report PNW-95. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 79 p.

Mobley, Hugh E.; Jackson, Robert S.; Balmer, William E.; [and others]. A guide for prescribed fire in southern forests. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area State and Private Forestry; 1978. 40 p.

Mutch, Robert W., tech. coord. Prescribed fire by aerial ignition: Workshop proceedings; 1984 October 30-November 1; Missoula, MT. Missoula, MT: Intermountain Fire Council; 1984. 217 p.

Norum, Rodney A. Preliminary guidelines for prescribed burning under standing timber in western larch/Douglas-fir forests. Research Note INT-229. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 15 p.

Noste, Nonan V.; Barney, Richard J. Vegetation recovery compared on blasted and hand-dug firelines. Research Note. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; [in press].

Noste, Nonan V.; Brown, James K. Current practices of prescribed burning in the West. In: Proceedings of the 1981 John S. Wright forestry conference; West Lafayette, IN. West Lafayette, IN: Purdue University; 1981: 156-169.

Puckett, John V. Users' guide to debris prediction and hazard appraisal. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1977. 34 p.

Rothermel, Richard C. BEHAVE and YOU can predict fire behavior. Fire Management Notes. 44(4): 11-15; 1983.

Sackett, Stephen S. Reducing natural ponderosa pine fuels using prescribed fire: two case studies. Research Note RM-392. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980a. 6 p.

Sackett, Stephen S. An instrument for rapid, accurate, determination of fuel moisture content. Fire Management Notes. 41(2): 17-18; 1980b.

Society of American Foresters. Forest cover types of North America. Washington, DC: Society of American Foresters; 1954. 69 p.

Society of American Foresters. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters; 1980.

Southwest Interagency Fire Council. Guide to prescribed fire in the Southwest. [Publication location unknown]: Southwest Interagency Fire Council; 1968. 58 p.

U.S. Department of Agriculture, Forest Service. Northern Region fuels management planning and treatment guide. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1987. 54 p. plus appendix.

van Wagtendonk, J. W.; Bancroft, L.; Ferry, G.; French, D.; Hance, J. T.; Hickman, J.; McCleese, W. L.; Mutch, R.; Zonteck, F.; Butts, D. Prescribed fire monitoring and evaluation guide. Washington, DC: National Wildfire Coordinating Group, Prescribed Fire and Fire Effects Working Team; 1982. 16 p.

Volland, Leonard A.; Dell, John D. Fire effects on Pacific Northwest forest and range vegetation. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1981. 23 p.

Warren, John R.; Vance, Dale L. Remote Automatic Weather Station for resource and fire management agencies. General Technical Report INT-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 11 p.

Weaver, Harold. Fire as an ecological factor in southwestern ponderosa pine forests. Journal of Forestry. 49: 93-98; 1951.

Weaver, Harold. Ecological changes in the ponderosa pine forest of Cedar Valley in southern Washington. Journal of Forestry. 57: 12-20; 1959.

Wright, Henry A. The effect of fire on vegetation in ponderosa pine forests: a state-of-the-art review. Publication T-9-199. Lubbock, TX: Texas Tech University, Department of Range and Wildlife Management; 1978. 21 p.

APPENDIX A: QUESTIONS ASKED DURING INTERVIEWS

1. Please give a general breakdown of your District's burning program:
   (Size of District: acres).

Type of Prescribed Burn	Approx. acres burned PIPO/DF/larch	All other
Dozer piles		
Hand piles		
Jackpot		
Broadcast		
Underburning		

2. Do you have ponderosa pine/larch/Douglas-fir type on your District?
   - –What percent of your District is in this type?
   - –Are you understory burning in this type?
   - –How many acres per year?
3. What are the purposes/objectives of your prescribed understory burning program?
   - –Depending on purpose, are there differences in timing or procedures?
   - –If so, break this down into these periods:
     - Spring
     - Other
     - Fall
   - –What disciplines do you bring together to decide on objectives?
   - –Do you consider historical fire frequency in developing your objectives?
   - –In partial cut units, how do you select species and sizes of leave trees?
4. How many acres have you understory burned by FY in the following categories?

	Acres	Cost/Acre
–Fuel reduction—natural		
—man-made (slash)		
–Site preparation		
–Wildlife and range		
–Other resources (viewing, soils, watershed, etc.)		

5. How do insects and disease (i.e. bark beetles, mistletoe, etc.) relate to your program? Does understory burning help solve insect problems or create them? If the latter, how do you mitigate them? Are problems short or long-term?
6. How do these topographic features impact your program?
   - –Aspect
   - –Percent slope
   - –Elevation
7. How do you develop your prescription window?
   - a. What sources of information or guidelines do you use?
   - b. What disciplines do you coordinate with?
8. What guidelines (or rules of thumb) do you use in understory burning PIPO/larch/DF?
   - a. Fuels:
     - –What fuel data is required? (down woody) (activity fuels) (live fuels) (duff)
     - –How is it obtained?
     - –How do you use fuel inventory to arrive at workable prescriptions? (less than 3″ fuels) (duff)
     - –What, if any, fuel models do you use to develop fire behavior predictions and in turn prescriptions? (TI-59 . . . BEHAVE) (flame length) (scorch height)
     - –What impact does crown closure have on the fuel moisture needed for an adequate burn?

(con.)

b. Weather:

-Do you use your statistical weather data to aid in developing your Rx window? How?

-What rules of thumb do you use to decide on preferred and acceptable weather parameters?

c. What ranges of weather parameters do you use:

	Preferred (range)	Acceptable (range)	Why?
Temperature			
Relative humidity			
Windspeed			
Direction			
Fuel moisture: 1-h 10-h 100-h 1000-h Duff (lower ½)			
Live fuel moisture			
Precipitation- (1 week prior to burn)			

d. Timing: When do you burn? Why?

-Seasons

-Time of day

9. Preburn preparations: What needed?

-Planning

-Onsite

-Fuel treatment—snag policy

-Firelines—natural

—man-made

-Leave tree protection

10. Ignition techniques: What do you use?

-Aerial vs. hand-torching?

-Firing pattern used?

If strip-head fire, what are widths of strips and how close should each person follow another?

How do you choose which technique? What are tradeoffs between ignition system and other variables?

-Communications needed:

11. Contingency Plan: What do you use? and how?

12. How would you define "escape potential?" Is this a large problem?

13. Monitoring/evaluation: What needed?

14. Guidelines for PIPO/DF: If developed, would they be useful? (What should be included in them?)

APPENDIX B: PRESCRIBED BURNING SPECIALISTS WHO WERE INTERVIEWED ON SELECTED DISTRICTS

Region	National Forest	District	Staff Fire Management Officer (and address)	Phone
1	Bitterroot	West Fork	William Frost, Mike Oliver Darby, MT 59829	(406) 821-3269
1	Flathead	Glacier View	Richard Lasko Columbia Falls, MT 59912	(406) 892-4372
1	Idaho Panhandle	Bonners Ferry	Robert Bosworth, Roy Wold Route #1, Box 390 Bonners Ferry, ID 83805	(208) 267-5561
1	Kootenai	Rexford	George Curtis P.O. Box 666 Eureka, MT 59971	(406) 296-2536
1	Kootenai	Yaak	Ronald Pierce Sylvanite Ranger Station Route #1 Troy, MT 59935	(406) 295-4717
1	Lolo	Superior	Ralph Parkin Superior Ranger District Superior, MT 59872	(406) 822-4233
6	Fremont		Tim Tyree 34 North D. Street Lakeview, OR 97630	(503) 947-2151
6	Fremont	Bly	Richard Johnson Bly, OR	(503) 353-2417
6	Fremont	Lakeview	Loren Lucore Lakeview, OR 97630	(503) 947-3334
6	Ochoco		Harry Clagg, John Maupin Box 490 Prineville, OR 97754	(503) 447-6247
6	Ochoco	Big Summit	Bruce Cheney Box 490 Prineville, OR 97754	(503) 447-3845
6	Ochoco	Paulina	John Robertson, Al Murphy Paulina, OR 97751	(503) 477-3713
6	Ochoco	Prineville	Jim Reser Prineville, OR 97754	(503) 447-6247
6	Ochoco	Snow Mountain	Mike Lehman Star Route 4-12870 Highway 20 Hines, OR 97738	(503) 447-6247

APPENDIX C: PRESCRIBED BURNING PROGRAMS ON 12 SELECTED DISTRICTS

Item	Glacier View (Flathead)	Bonners Ferry (Idaho Panhandle)		Yaak (Kootenai)		Rexford (Kootenai)		Superior (Lolo)		West Fork (Bitterroot)	
District size (acres)	300,000	450,000		360,000		311,000		475,000		796,000[1]	
Acres of prescribed burning	All types	All types	DF/larch	All types	DF/larch	All types	PIPO/F/L	All types		All types	PIPO/DF
–dozer piles	200	889	289	1,687	675	450	50	125		150	100
–hand piles	15	80	40	–	–	10	–	15		200	150
–jackpot	–	–	–	–	–	100	100	–		300	200
–broadcast	300	480	240	205	80	500	100	500		50	25
–underburning	120	270	–	250	105	100	900	125		500	400
Pine/larch/fir type		DF/larch + PIPO total	PIPO/DF	DF/larch + PIPO total	PIPO/DF larch	Other types	PIPO/F/L	DF/larch total	PIPO/DF	DF/PIPO total	PIPO/DF
–percent of District	–	22	4	30	5	–	35	24	15	75	75
–acres	–	100,000	20,000	108,000	18,000	–	109,000	118,000	71,000	220,000	220,000
–understory burning acres	–	270	–	250	105	–	1,150	200 +	380	600	600

(con.)

APPENDIX C (Con.)

Item	Lakeview (Fremont)		Bly (Fremont)		Prineville & Big Summit (Ochoco)		Paulina & Snow Mountain (Ochoco)	
District size (acres)	340,000		325,000		412,000		465,000	
Acres of prescribed burning	PIPO	PIPO Assoc.	PIPO	PIPO Assoc.	S-facing PIPO	N-facing PIPO Assoc.	PIPO	PIPO Assoc.
–dozer piles	2,000	3,500	400	4,000	3,700	1,000	750	1,550
–hand piles	–	–	33	33	–	250	–	–
–jackpot	–	–	–	–	500	2,450	2,000	2,500
–broadcast	200	300	200	500	–	350	–	330
–underburning	2,000 (1,500 acres contain 25% white fir in understory)	–	1,400	200	2,500	300	2,000	1,200
PIPO/DF/larch type								
–percent of District	87		85		95		85	
–acres	295,000		275,000		391,000		395,000	
–understory burning acres	2,000		1,600		2,800		3,200	

[1]503,000 acres on the West Fork District are wilderness; 293,000 acres are nonwilderness, 170,000 acres of which is commercial forest.

APPENDIX D: UNDERSTORY BURNING PROGRAMS AND COSTS ($/ACRE) BY OBJECTIVES FOR 12 SELECTED DISTRICTS[1]

Acres burned and costs by objective	Glacier View (Flathead)		Bonners Ferry (Idaho Panhandle)		Yaak (Kootenai)		Rexford (Kootenai)		Superior (Lolo)		West Fork (Bitterroot)	
	Acres	Cost	Acres	Cost	Acres	Cost	Acres	Cost	Acres	Cost	Acres[2]	Cost
Fuel reduction												
–natural			270[3]	74	180	n.a.	300	7-15	40	20-70	80	35
–slash							580	70-150	70	30-75	895	68
Site preparation							580	70-150	70	30-75	475	–
Wildlife and range			50	50	200	6-12	800	2-10	185	5-15	20	–
Other (recreation)			–	–	–	–	50	10-20	14	8-10	–	–
General costs												
–spring		68		50		6-12		2-30		5-40		8-70
–fall		120-160		74		70-250		70-130		250		25-155
–fall jackpot								15-40				

(con.)

APPENDIX D (Con.)

Acres burned and costs by objective	Lakeview (Fremont)		Bly (Fremont)		Prineville & Big Summit (Ochoco)		Paulina and Snow Mountain (Ochoco)	
	Acres	Cost[4]	Acres	Cost	Acres	Cost	Acres	Cost
Fuel reduction								
–natural	1,100	18-20	1,600[5]	25-30	1,750	10-25	1,000	2-25
–slash	750	25	400	35	1,500	25-80	2,400	10-60
Site preparation	–	–	85	35-45	280	100-250[6]	200	20-100
Wildlife and range	150	18-20	–	–	1,400	10-30	500	2-15
Other (TSI)	–	–	–	–	–	–	100	30-60

[1]Costs include District overhead plus all project expenditures. They do not include overhead costs beyond the District.
[2]The 475 acres of site preparation and 20 acres of wildlife burning are also included in the 80 plus 895 acres of fuel reduction, because these were multiobjective burns.
[3]Fuel reduction and site preparation are combined for the Bonners Ferry and Yaak Districts.
[4]Lower ends of cost ranges generally reflect spring or late fall burning when line building and mopup are unnecessary.
[5]1,600 acres of fuel reduction also benefits wildlife.
[6]$100 costs on south-slope, with $250 costs on north-slope.

APPENDIX E: SAMPLE UNDERSTORY BURN PLAN IN PONDEROSA PINE/DOUGLAS-FIR

BURNING PLAN COVER PLAN

5150

PRESCRIBED BURNING PLAN

MUD LAKE
Burning Unit

REXFORD Ranger District

Kootenai National Forest

Prepared By: /S/ RONALD J. HVIZDAK Date: 2/11/83

Prepared By: /S/ GEORGE A. CURTIS Date: 2/14/83

Prepared By: /S/ DONALD GODTEL Date: 2/16/83

Prepared By: /S/ BOB SEIDEL Date: 2/23/83

Prepared By:________________ Date:________

Prepared By:________________ Date:________

The approved Prescribed Burning Plan constitutes the authority to burn. No one has authority to burn without an approved plan or in a manner not in compliance with the approved plan. Actions taken in compliance with the approved Prescribed Burning Plan will be fully supported. Personnel will be held accountable for actions taken which are not in compliance with the approved plan, regardless of the outcome of the burn. The same level of authority required to approve the Prescribed Burning Plan is required to amend the plan. This project and plan are rated as Complex X , Intermediate____, Non-Complex____, pursuant to R-1, 1981, Fuel Management and Treatment Guides.

Approved by: /S/ DAVID E. PONCIN Date: 3/4/83

(con.)

ACCOUNTING COST: 132053
EST. COST/ACRE: $5.00
FINAL COSTS:
TOTAL COST/ACRE: $4.00

SALE: MUD LAKE WINTER RANGE Unit:
LOCATION: T 36N R 28W N 1/2 SEC. 25
STAND: 16-3-14, 95, 02 ACRES: 320 ELEVATION: TOP 4000 BOTTOM 3100
DRAINAGE: PINKHAM CREEK SLOPE: 20-40 % ASPECT: S-SW
HABITAT TYPE: DF/Syal/Caru NFDR FUEL MODEL: A,C,U F,B,FUEL MODEL: 2,9

FUELS: NATURAL X ACTIVITY X AGE ___ YRS ASSESSMENT: L__ M X H__
DOWN WOODY PRIVATE PROPERTY ADJACENT 100 yards over the ridge
0-1/4" 0-1.0 T/A DUFF DEPTH 1-2" IN. FUEL DEPTH 0-1'
1/4-1" 0.5-2 T/A TOTAL FUEL 2.0-12.0 T/A
1-3" 0.5-4 T/A ADJACENT FUEL Similar fuel type in places, but on
3+" 1-5 T/A different aspect and will be damp in spring.

OBJECTIVES OF BURN (CHECK)		(RANGE OF ACCEPTABLE RESULTS)
HAZARD REDUCTION	X	Reduce 3" minus fuel loadings to <3 T/acre with old logging, xmas tree, & thinning slash
SILVICULTURE		
SITE PREPARATION		
WILDLIFE HABITAT	X	Stimulate browse and grass production; reduce excessive conifer cover of 2" d.b.h. class by 25%.
RANGE MANAGEMENT	X	Maintain open grassy slopes & meadows that are being invaded by fir.
OTHER		

PRESCRIPTION

TEMPERATURE:	50	TO	75
R.H.	20	TO	35
WIND SPEED	2	TO	10
DIR.	S (Preferred)		SW - East (Accepted)
ERC	-	TO	-
BI	-	TO	-
RATE OF SPREAD	2	TO	15
FLAME LENGTH	2	TO	4
SCORCH HEIGHT	3	TO	15

SEASON: Spring TIME: 1100-1700

FUEL MOISTURE	INSIDE			OUTSIDE		
0-1/4	7	TO	10	8	TO	+
1/4-1	9	TO	13	13	TO	+
1-3	15	TO	20+	15	TO	20+
DUFF (LOWER)	-	TO	-	-	TO	-
SHRUBS	50	TO	150	50	TO	150

IGNITION METHOD Drip Torches or fusees

FIRING PATTERN Strip head fires

EXPECTED FIRE BEHAVIOR Fire will burn rapidly through the open, grassy slopes and may crown out some trees, especially those with branches all the way down to the ground. Spread will be slower on the more level area. The young tree cover is thick in some areas, however, and isolated torching out may occur.

PREPARATION:
TYPE OF FIRELINE: HAND 10-15 TRACTOR ____ CREW SIZE: IGNITION 5 HOLDING 4
PORTATANKS ____ PUMPS ____ HOSE 1000' TANKERS 1-300 SHOVELS 5 PULASKIS 8
SAWS 2 TORCHES 6 FUEL 25 gal. - slash RADIOS 7
PREPARATION NEEDED PRIOR TO BURN Handline down the spur ridge along east side near the private land. Preburn along this line and ridge before actually burning the unit.

(con.)

FIRING AND HOLDING PLAN: (See attached map or photo) Burning this unit will be done in 3 stages. First, the area along the east side will be burned early in Spring to anchor the line near the private land. The next step will be to burn the open grassy slopes at a later date, unless they would burn well the initial day. The third step would be to burn the timbered area between the two meadows plus the remaining flat area where dry enough. Holding: Two people plus a 300 gallon tanker, patrol handline near private land on east flank. Also 2 people will patrol the west flank with a 4X4 with water.

HAZARD AREA: (See attached map or photo) There is private land both to the east and west. The east land is the more critical as it is downwind of the burn. Precautions will be made to insure both of these area's safety.

MOP UP AND PATROL PROCEDURES: Some mopup may be needed along the east flank the day after the burn. The unit will be patrolled daily until it is considered safe or out.

TEST FIRE: (If applicable) Should not be necessary.

SMOKE MANAGEMENT: Smoke will likely drift over the town of Eureka, but it should disperse rapidly in the spring time.

SAFETY:

Public: Private landowners will be notified when any burning will take place and kept up to date on its status after the burn.

Burn Crew: Communications will be the key to this burns safety record. It is a large area and each torchman must be in contact with one another as to location and progress. The holding crews must also keep in contact with the burn boss; also see safety and health hazard analysis.

I & I CONTACTS: An article will be put in the Tobacco Valley News.

REMARKS: Signs will be placed along the Prikham road. (Not done as planned, signs were put out the following day.)

(con.)

PREBURN INFORMATION:

FUEL MOISTURE %:

DATE	0-1/2"	1/4-1"	1-3"	3"+	DUFF	PRECIP
4/6/83	7-8	9-10	15-20	20+	NA	1/4 (/30) .12(3/31- 4/1 &4/2)

BURN MONITORING: DATE: 4/6/86 TIME OF IGNITION: 1325 STOP: 1730

BURNING BOSS: Curtis FIRING BOSS: Hvizdak HOLDING BOSS: Young

ACTUAL WEATHER:	TEMPERATURE	R.H.	WIND SPEED/DIRECTION		STATE OF WEATHER
1 HOUR BEFORE	53 F	35 %	0-3 MPH	W-NE	Clear
START	60 F	30 %	0-3 MPH	NE top, NW bottom	Clear
30 MINUTES	same F	same %	same MPH	W-NW	Clear
60 MINUTES	61 F	26 %	3-5 MPH	W-NW	Clear
180 MINUTES	59 F	35 %	3-8 MPH		
	F	%	MPH		
	F	%	MPH		
	F	%	MPH		

FUEL MOISTURES %: 0-1/4" 7 1/4-1" 9 1-3" 15 DUFF - SHRUB -

FIRE BEHAVIOR RATE/SPREAD 2-7 CH/HR, ERC ______, x FLAME LENGTH 2-8 FT.

x FLAME HEIGHT 1-6 x SCORCH HEIGHT 5-30 FT.

POST BURN EVALUATION (Objectives Met?) Burned open meadows and east line next to private land 2 weeks prior to this. Heavy timber between two meadows burned only fair as expected. The remainder of unit below meadows burned good. Several pockets of thick reproduction burned out in this understory burn. This should release bunchgrass and seral shrubs to increase forage for cattle and big game.

CONTINGENCY PLAN:

FIRE BEHAVIOR FUEL MODEL NO. 9 DISCUSSION: There is an aspect change into the area downwind of the unit, which would slow down the spread, especially in early March.

FIRE BEHAVIOR INPUTS "HOTTEST" CONDITIONS: SHADE 3 DRY BULB 75 RH 20

1 HR 8 10 HR 13 100 HR 15 LIVE ______ WIND SPEED 4

PROJECTION TIME 1 hour

PREDICTED FIRE BEHAVIOR: ROS 6 CHS/HR HT/UNIT ARE 343 FIRELINE INTENSITY 37

FLAME LENGTH 2 PERIMETER 19 CHS. AREA 2 ACRES

PLAN OF ACTION: NO. OF PEOPLE 10 FROM WHERE Eureka District

ETA 30 mins LINE TO BUILD 19 MAX. ACRE ALLOWED 1 TIME NEEDED 1 hr

PLAN OF ACTION: If preburn is successful, no problems should result. If not, and a spot results during the burn, a tanker with ample hose will be on the spot to slow it down. The burn crew should be able to handle any problems. Additional help is only 15 to 30 minutes away, at the Eureka Ranger Station.

APPENDIX: E (Con.)

BURNING PLAN AMENDMENT 1/

NEED FOR AMENDING PLAN

EFFECT OF AMENDMENT ON BURN OBJECTIVES

REVISED PRESCRIPTION: Temp: Upper___Lower___R.H.%: Upper___Lower___Season____
Time:___Wind Direction: Preferred:___Acceptable:___Speed:___to___________
Moisture Content: 0-1/2___ 1/4-1___ to ___% 1-3___ to___% 3+___ to___%
Duff: Upper___to___% Lower___to___% Live___to___%
NFDR: ERC: Max____ Rate/Spread___ CH/HR Max. Flame Height______ Ft.
Fireline: Hand____ Mech.________Ignition Method_________________________

EFFECT OF AMENDMENT ON CONTINGENCY PLAN

REVISED CONTINGENCY PLAN

Fire Behavior Fuel Model No._____ Discussion:_____________________________

____

Fire Behavior Inputs "Hottest" Conditions: Shade____ Dry Bulb___RH________
1 HR_____10 HR_____100 HR_____Live_____Wind Speed_____ Projection Time________
Predicted Fire Behavior: ROS_____CH/HR HT/Unit Area_____Fire Intensity________
Flame Length________Perimeter________CHS. Area_____________ACS
Plan of Action: No. of People_______ From Where_____________ETA__________
Line to Build:________________ Max. Acre Allowed_____Time Needed__________

Plan of Action:____
____
____
____
____

BURNING PLAN AMENDMENT APPROVAL

APPROVED BY:________________________________ DATE:____________________

1/ This amends the burn plan in the field if major changes in weather or fuel parameters occur on site.

Kilgore, Bruce M.; Curtis, George A. 1987. Guide to understory burning in ponderosa pine-larch-fir forests in the Intermountain West. Gen. Tech. Rep. INT-233. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 39 p.

Summarizes the objectives, prescriptions, and techniques used in prescribed burning beneath the canopy of ponderosa pine stands, and stands of ponderosa pine mixed with western larch, Douglas-fir, and grand fir. Information was derived from 12 districts in two USDA Forest Service Regions and seven National Forests in Montana and Oregon.

KEYWORDS: fire prescriptions, ignition techniques, fire management, prescribed fire, site preparation, fuel management, silviculture, ponderosa pine, western larch, grand fir, forest management

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

General Technical
Report INT-234

Utilizing Wood Residue for Energy Generation in Northwestern Montana: A Feasibility Assessment

**Charles E. Keegan III
Timothy P. Jackson
Richard P. Withycombe
Roland L. Barger
Alfred L. Chase**

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

October 1987
Intermountain Research Station
324 25th Street
Ogden, UT 84401

THE AUTHORS

CHARLES E. KEEGAN III is director of Forest Industry Research, Bureau of Business and Economic Research, University of Montana, Missoula, MT.

TIMOTHY P. JACKSON is research specialist, Bureau of Business and Economic Research, University of Montana.

RICHARD P. WITHYCOMBE is professor of management, School of Business Administration, and research associate, Bureau of Business and Economic Research, University of Montana.

ROLAND L. BARGER was program manager (now retired), Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Forestry Sciences Laboratory, Missoula, MT.

ALFRED L. CHASE is forestry instructor, Missoula Vocational Technical Center, Missoula, MT.

RESEARCH SUMMARY

Insufficient assessment of local, site-specific opportunities is frequently cited as a barrier to improved utilization of wood residues. To provide comprehensive information for a Northern Rocky Mountain site, a study was undertaken to assess utilization feasibility for power generation in northwestern Montana. The study area chosen was the heavy timber-producing area within an approximate 100-mile radius of Libby, MT.

Wood residue potentially available in the study area includes both mill and forest residue. Unutilized fine mill residue and bark totaling approximately 100,000 cunits annually is available at $10 to $30 per cunit, given lumber production at or above normal levels. Forest residue, including logging residue, material cut in thinning or other stand improvement operations, older residues, and dead and cull trees on unlogged areas, is also available but frequently at a relatively high cost of recovery. The most promising source of forest residue is top, limb, and cull section recovery from sawtimber through whole tree harvesting and processing methods. Approximately 120,000 to 200,000 cunits of this residue could be available annually at an average cost of $45 per cunit. An additional 41,000 cunits of cull logs are available annually in the supply area at an average cost of $65 per cunit.

Economic feasibility was evaluated for four theoretical power-generating facilities—cogeneration facilities of 5 and 15 megawatt capacity and stand-alone facilities of 15 and 25 megawatt capacity. All represent facilities that could be supplied by the available wood resource in the study area. At a levelized or constant electrical power buyback rate of 6.27 cents per kilowatt hour and baseline industry capital investment levels, none of the facilities could provide an internal rate of return that would be economically attractive. If capital costs are reduced by 25 percent, however, economic feasibility can be demonstrated at low ($5-$20 per cunit) wood costs. At a further reduced capital investment of $1 million per megawatt of capacity, which can be achieved with refurbished equipment, wood fuel costs in excess of $20 per cunit are economically acceptable. The use of forest residue at $45 to $65 per cunit does not appear to be economically feasible except under combinations of substantially reduced capital costs and increased buyback rates.

A final analysis evaluated the feasibility of utilizing wood as a substitute fuel for natural gas or fuel oil in process steam boilers. Under conditions where the increase in capital cost to accommodate wood is no more than 2.5 times that required for fossil fuels, wood appears to be an economically attractive substitute. At relatively high levels of boiler capacity utilization, wood costs of $50 and over per cunit can be borne. Inconveniences associated with wood, such as storage area needed, fire hazard, and handling requirements, may have a major influence on whether wood is considered as a fuel.

Improved utilization of wood residue for energy in northwestern Montana appears to be constrained primarily by the cost of recovery of residue material and the relatively low value of energy produced. Other barriers include a complex State permitting process, short supply contract periods compared to fossil fuels, and environmental concerns about extreme levels of biomass removal.

CONTENTS

Utilizing Wood Residue for Energy Generation in Northwestern Montana: A Feasibility Assessment

Charles E. Keegan III
Timothy P. Jackson
Richard P. Withycombe
Roland L. Barger
Alfred L. Chase

INTRODUCTION

Although timber utilization practices have improved significantly in recent years, large volumes of wood residue remain unused (fig. 1). An increase in wood residue utilization depends on such factors as availability, accessibility, outlook for continued supply, cost of recovery, and value of potential products or uses.

A recent General Accounting Office report (U.S. General Accounting Office 1981) identified one of the barriers to improved utilization as insufficient assessment of residue utilization opportunities on a localized, site-specific basis. More comprehensive information for specific areas is considered essential for predicting future wood supply, for conducting economic feasibility analyses, and ultimately for industrial planning and capital investment. To provide this kind of comprehensive information for a Northern Rocky Mountain site, a cooperative project was undertaken by the Intermountain Research Station, Forest Service, U.S. Department of Agriculture, and the Bureau

Figure 1—Unused residue remaining on site following sawtimber harvesting, including small stems and unmerchantable cull material, is equivalent to about 50 percent of the total volume contained in merchantable trees cut.

of Business and Economic Research, University of Montana.[1]

The study area chosen for this project was the area comprising the timber supply zone for primary wood products manufacturers in Libby, MT (fig. 2). The area was chosen for the following reasons:

- Northwestern Montana is one of the largest timber-producing regions in the Inland Northwest.
- Libby is a major wood products producing center.
- Historic harvest levels and species composition indicate that large volumes of forest residue should be available in the area.
- Most of the timber harvest activity occurs on National Forest lands or industrial forest lands, making resource data more readily available.
- There is substantial local interest in residue utilization for power generation.

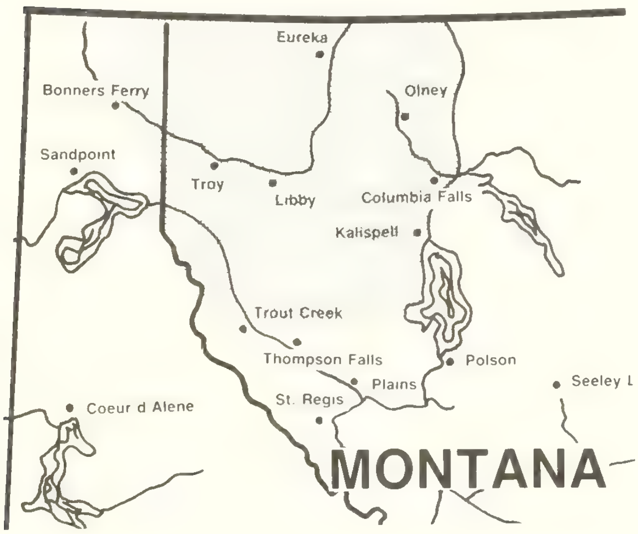


Figure 2—The study was focused on timber-producing lands within an approximate 100-mile radius of Libby, MT.

OBJECTIVES AND SCOPE

The principal objective of this project was to develop the detailed information necessary to assess the feasibility of increased wood fiber residue utilization. The emphasis is on the use of wood residue for electrical generation in northwestern Montana, although much of the information could be used to assess other utilization opportunities as well. An additional objective was to develop and demonstrate methodology that could be applied in other geographic areas to analyze residue availability in a similar manner.

The study involved a series of investigations, each addressing a particular factor that would influence the feasibility of recovering and using residue to generate power. Specific components of the overall study included:

1. Developing detailed estimates of present and future wood residue volumes, locations, characteristics, and availabilities in the study area.
2. Estimating the costs of recovering residue of various types.
3. Evaluating current and future trends in other wood-based industries and assessing competition for the wood resource.
4. Evaluating the financial feasibility of using residue for electrical power generation and as a substitute for other fuels.
5. Identifying additional barriers to increased residue utilization and benefits from utilization.

Each of these components is discussed in some detail in this report, because each is of interest as an independent subject, as well as in terms of the aggregate feasibility analysis. Other publications resulted from some of these investigations and are referenced in the appropriate sections.

WOOD RESIDUE AVAILABILITY AND COST

Wood fiber residue in northwestern Montana has two major components: mill residue and forest residue. Mill residue is wood fiber residue generated from processing logs into lumber, plywood, and other wood products. Forest residue is that component of the available timber resource not currently being utilized. It includes slash from logging operations and road right-of-way projects, dead and cull green material on sites not scheduled for logging, and small stems from timber stand improvement projects.

Unutilized mill residue generally is much cheaper than forest residue. But much of the mill residue in the region is committed. Therefore, a new facility producing power may have to compete for mill residues (Keegan and White 1979). Because mill residue is relatively inexpensive when available, it was studied in detail.

The most promising source of forest residue in large volumes is conventional sawtimber harvesting operations. This kind of residue, referred to as logging residue, is the cheapest and most accessible type of forest residue available and received special attention in this project. Other kinds of forest residue were assessed in less detail.

Mill Residue Availability and Cost

All plants processing timber into primary wood products generate mill residue. But more than 95 percent of the mill residue generated in the Inland Empire comes from sawmills and plywood plants (fig. 3). This analysis evaluates mill residue from only sawmill and plywood operations across the Inland Empire (fig. 4).

The three types of mill residue generated at sawmills and plywood plants are: (1) coarse or chippable residue consisting of slabs, edgings, and trim from lumber manufacturing, log ends from sawmills and plywood plants, pieces of veneer not suitable for plywood manufacture,

[1]The research project reported here was funded largely by Energy Security Act funds made available to the Forest Service, U.S. Department of Agriculture.

Figure 3—More than 50 percent of the volume of logs entering the millyard will become mill residue in the form of bark, sawdust, trim, and shavings.

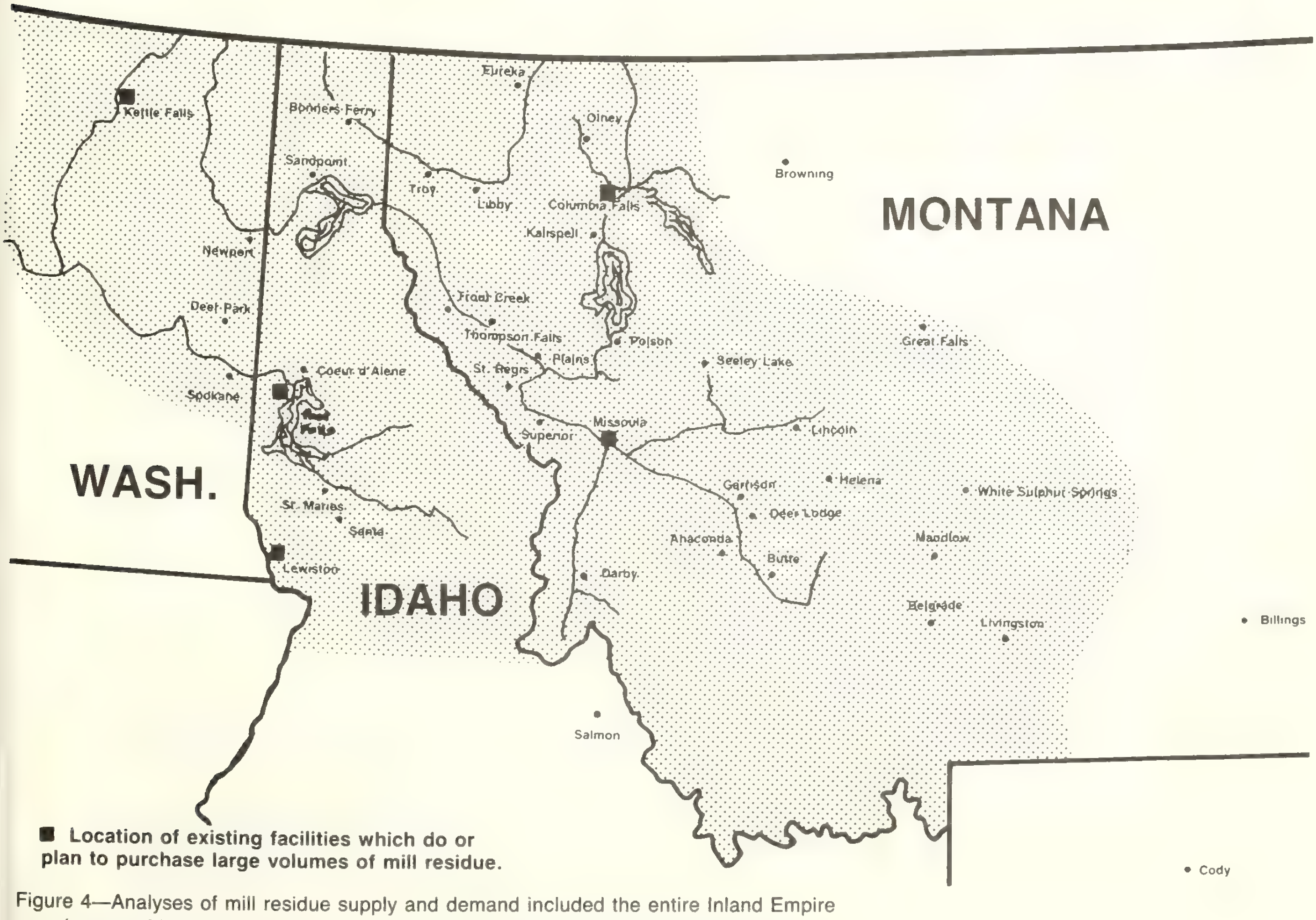


Figure 4—Analyses of mill residue supply and demand included the entire Inland Empire area (western Montana, northern Idaho and eastern Washington); however, residue availability for a generating facility in the Libby area is principally focused on northwestern Montana and northern Idaho.

and plywood peeler cores not sawn into lumber; (2) fine residue consisting of planer shavings and sawdust from sawmills and sander dust from plywood plants; and (3) bark from sawmills and plywood plants.

The estimates of annual supply of mill residue were developed by applying mill residue volume factors to projected lumber and plywood production in the region for a year of normal or average demand for lumber and wood products. Annual demand estimates for mill residue were based on the volume of wood fiber that existing residue-utilizing facilities required to operate at capacity. Additionally, the volume of residue needed as fuel to dry lumber and veneer was based on assumed mill production (Keegan and Jackson 1985).

Coarse residue is utilized primarily as a raw material by the pulp and paper industry. Fine residue is used as a raw material for the pulp and board industry and for fuel, while bark residue is used almost exclusively for fuel. There is a large demand for coarse residue within the Inland Empire, and accompanying the high demand is its higher price—$30-$80/cunit FOB producer's mill, versus under $10 for fine residue and bark (Keegan and others 1982, 1983). (A cunit is 100 ft^3 of solid wood, weighing approximately 2,500 lb ovendry.) A new user, such as a power-generating facility using fine residue and bark, would certainly try not to compete for coarse residue and concentrate on the lower cost residue components.

DEMAND VERSUS SUPPLY

The Inland Empire's estimated annual supply of mill residue should exceed regional demand in a normal year by nearly 460,000 cunits (table 1). Sawmills and plywood plants will generate just over 3.95 million cunits in a normal year, while estimated requirements from users within the region are 3.49 million cunits. Virtually all of the 270,000 cunits of excess coarse residue is utilized by manufacturers out of the region (Keegan and Jackson 1985).

Projected supplies of fine residue and bark should exceed demand by 190,000 cunits for a year of normal lumber and plywood production. Between 100,000 and 120,000 cunits of this unused fine residue and bark would be generated at mills in Lincoln County, MT, and adjacent counties in northern Idaho and northwestern Montana. Canadian mills nearest Libby could supply an additional 30,000 to 50,000 cunits not included in the 190,000 mentioned above.

The entire volume of unused fine residue and bark would not necessarily be readily available. For example, some of the excess would be at small mills, where the high fixed cost associated with chipping, hogging, and storing residue may make recovery uneconomical. Users in northwestern Montana should, however, be able to conservatively contract annually for volumes of unutilized fine mill residue and bark of slightly more than 100,000 cunits, given lumber production levels at or above normal levels. This material, delivered to a user in Lincoln County, would certainly cost less than recovering forest residue. Delivered costs for fine residue and bark should range between $10 and $30 per cunit. Cost to a mill utilizing its own excess residue would be lower—an estimated $5 per cunit. As will be discussed later, competition could make the price of bark and fine mill residue considerably higher in the future. In addition, if a user required the entire 100,000+ cunits annually, it would probably be necessary to either sharply curtail operations during periods of lower than normal lumber production or rely heavily on forest residue.

Forest Residue Availability and Cost

Timberlands in the Northern Rocky Mountains hold large quantities of wood fiber which are neither sawtimber nor desirable growing stock. Much of it is not currently utilized and would fall into the general category of forest residue. For purposes of this analysis, forest residue was defined as:

1. Logging residue which consists of dead and cull green material, including crowns and unmerchantable bole tips, currently left on logging sites.
2. Material cut and left on site following timber stand improvement practices, such as thinning or stand conversion operations.
3. Material remaining from past logging operations.
4. Dead, small, and cull green trees on sites not scheduled for commercial harvesting operations or timber stand improvement.

Table 1—Estimated annual supply and demand for mill residue in the Inland Empire during a normal mill production year[1]

	Coarse residue[2]	Fine residue[3]	Bark	Total
	Thousand cunits			
Supply from sawmills and plywood plants	1,880	1,285	790	3,955
Less: Expected demand for raw materials from pulp and board plants	1,610	595	—	2,205
Residue available for use as hogfuel	—	690	790	1,480
Less: Expected demand for hogfuel	—	1,290		1,290
Projected residue excess from sawmills and plywood plants	270	190		460

[1]Compiled from: Bureau of Business and Economic Research (1977, 1981, 1982), Cody (1980), Forest Products Journal (1982), Larsen and Gee (1981), and U.S. Department of Energy (1982).
[2]Material suitable for chipping such as slabs, edgings, and trimmings.
[3]Material such as sawdust and planer shavings.

The potential of these sources to supply major users of wood fiber in the Libby area was examined. The boundaries of the supply zone, illustrated in figure 2, were established based on current transportation networks and industry practices. Specifically, the objectives were to estimate: (1) the volumes of the various components of forest residue available annually for the period 1986 to 1995, within a 100-mile haul of Libby, MT, and (2) the cost of recovering that material. Forest residue volume estimates were based on residue volume factors applied to harvest levels or land area available for treatment. Appendix A contains a detailed discussion of the methodology used to estimate forest residue availability. Cost estimates were made based on a cost model for recovering forest residue in the Northern Rocky Mountains (Jackson and others 1984b). Availability and cost were evaluated for each of the four forest residue components individually.

LOGGING RESIDUE

One type of forest residue—logging residue—appears to offer the greatest opportunity; consequently, the analysis of this component received major attention. Logging residue availability and cost in the study area was evaluated based on three recovery systems. These were: (1) relogging (recovering residue in a secondary operation following logging); (2) log-length residue recovery at the time of sawtimber harvest to recover, in log lengths, large cull trees and cull portions of sawtimber trees currently left on logging sites; and (3) recovering whole trees either by processing them at the logging site to recover tops, crowns, and submerchantable stems, or by hauling whole trees (sawtimber and submerchantable stems) to the mill site where the sawtimber is to be processed. Details of the logging residue analysis are included in appendix A.

Relogging—The estimated cost of relogging sites was $90 per cunit in 1984 dollars. This cost is so high that it would preclude this system as a reasonable source for all but a very low volume or high-value end user. Low-volume users such as home fuelwood dealers or small-volume cedar products loggers with, for example, a chainsaw and a pickup truck may find recently logged sites on which they can recover material much more cheaply than $90 per cunit. Given the characteristics of the residue identified in the inventory, however, it appears that even these opportunities are limited.

Log-length Residue Recovery—A log-length recovery system to capture large cull logs and cull portions of the bole of sawtimber trees in conjunction with the sawtimber logging operation appears to offer limited potential (fig. 5). Small volumes may be available relatively inexpensively if cull portions of sawtimber trees are recovered. Estimates show that for the entire Libby supply zone with a harvest of 440 million bd ft (Scribner scale) of sawtimber, an additional 38,000 cunits would be available annually if cull portions of the bole of sawtimber trees now left on logging sites were recovered. The estimated cost of the 38,000 cunits would be $30 per cunit. Volumes of large, sound cull logs remaining on sites in the area would be more expensive to recover. Costs are estimated to be $65 per cunit for the 41,000 cunits available annually on all sites suitable for tractor logging, and over $80 per cunit for the 17,000 cunits on sites suitable only for cable systems.

Figure 5—Cull logs and portions of trees recovered during conventional sawlog harvesting offer one source of available wood fiber.

Whole Tree Logging—Whole tree recovery systems can provide the lowest cost forest residue available in large volumes for use as fuel (fig. 6). This source would not be suitable for uses such as pulp and paper or most reconstituted board products that require clean, bark-free material, and therefore would avoid competition for other uses. Mills in the area receiving sawtimber would probably find whole-tree hauling, with subsequent processing at the mill, the cheapest source of wood fiber. A large-volume user independent of a sawmill or a plywood plant might find contracting for in-woods processing of whole trees a cheaper system than hauling to the plant. In either case, cost estimates range from $25 to $65 per cunit, with a suggested average of $45 per cunit in 1984 dollars. Estimated recoverable volumes at these costs are 120,000 cunits annually for in-woods processing, or 200,000 cunits if whole trees were processed at the mill.

OTHER COMPONENTS OF FOREST RESIDUE

Other components of forest residue include material from timber stand improvement projects, older slash, dead and cull material on unlogged sites, and insect-killed timber. Residue from timber stand improvement projects in the study area includes two general types of material: residue from precommercial thinning operations and residue from the conversion of stagnant stands of lodgepole pine to properly stocked stands of seedlings. In both cases, the trees available are small (below 7 inches d.b.h.) and expensive to recover. Based on discussion with land managers in the area, to prevent damage to the leave trees, mechanized felling and bunching would not be allowed on many of the sites scheduled for thinning. Because hand felling and bunching to recover large volumes would be extremely expensive (over $75 per cunit chipped and delivered), this component was not viewed as a viable source of wood fiber.

Material from stand conversion would be a more viable, although still expensive, source of wood fiber residue (fig. 7). At present there are about 75,000 acres of stagnant lodgepole pine stands in the regulated timber based on the Kootenai National Forest (Park 1984). Other ownerships in the area should offer 20,000 to 30,000 additional acres (Montana Department of State Lands 1982). Adjacent National Forests would increase the acres available. Estimates made by the USDA Forest Service indicate 15 to 20 cunits of recoverable wood fiber per acre on these sites. Total volumes potentially available would certainly exceed 1.5 million cunits from stand conversion operations. Because the material is small and expensive to recover, however, harvesting opportunities can reasonably be considered only on sites that would not require road construction, situated on relatively flat terrain, with stands averaging 4 inches or more in d.b.h.

If harvest activities were limited only to sites that will be accessed by road in the next 15 years on slopes less than 20 percent, fewer than 3,000 acres total would be available (Park 1984). Even if the slope restriction were raised to 40 percent, not more than 10,000 of the approx-

Figure 6—Whole-tree logging and processing systems, now common in the Northern Rocky Mountains, provide the lowest cost forest residue available in large volumes.

Figure 7—Extensive acreages of small, stagnated lodgepole pine offer a large, but relatively expensive, wood fiber resource.

imately 100,000 acres in need of conversion would be available. Given a 15-year liquidation period, less than 10,000 cunits would be available annually from sites with slopes under 20 percent. An estimated 20,000 cunits annually would be available on sites with slopes between 20 and 40 percent.

Given an equal volume distribution of 4- and 6-inch diameter material recovered using small feller bunchers on slopes under 20 percent, and a 50-mile one-way haul, delivered costs for whole-tree chips from these stands would exceed $65 per cunit. On slopes greater than 20 percent, large feller bunchers would be necessary and estimated costs would exceed $80 per cunit.

In addition to wood fiber from recently completed logging operations, wood residue is available in the form of untreated slash from logging operations completed in the last 10 to 15 years. In the mid-1970's, untreated slash in the Northern Region represented a very large volume of material (USDA FS 1974). Since the mid-1970's, however, slash treatment has generally kept pace with harvesting operations, and large volumes of untreated slash for more recent years would, therefore, not be available. The inventory of logged-over lands completed as part of this project also indicates greatly improved slash disposal and treatment.

Volumes of backlog slash that were available would be generally more expensive to recover than the cost per cunit estimated in the analysis of relogging recently logged lands. Backlog slash areas could not, therefore, be expected to contribute a significant amount of wood fiber to a potential user of any size.

There is an enormous quantity of dead and cull green timber in the Northern Rocky Mountains, much of which occurs in stands unlikely to be logged for sawtimber. But much of it is far from roads, scattered, and relatively expensive to recover. The unit cost of a logging operation is very dependent on the volume per acre to be removed, generally decreasing as more volume per acre is removed. The selective logging of dead and cull green material would consequently be more expensive than the harvesting of the same material in conjunction with a sawtimber harvesting operation in which much larger volumes per acre were harvested. Some selective logging of dead timber does occur in the Northern Rocky Mountains, however, especially for firewood and high value products such as house logs.

An infestation of mountain pine beetle in the supply area has reached epidemic proportions. It is anticipated that all lodgepole pine stands over 80 years old and 6 inches in diameter on the Kootenai National Forest will be infested by the mountain pine beetle within the next 10 years (USDA FS 1982). This represents a volume of just under 3 billion bd ft. The Kootenai National Forest has undertaken a large salvage program aimed at recovering the impacted lodgepole pine timber for lumber production. Because the wood products industry in the area has a limited capability to process lodgepole pine, and because of constraints imposed by accessibility and other resource values, harvest levels will be much lower than anticipated losses. Given present recovery rates, only about one-third of the 3 billion bd ft of dead lodgepole pine will have been recovered by 1995. Since at that time much of the pine will have been dead for more than 10 years, its potential for lumber recovery will be greatly reduced. Beetle-killed pine could then become a major source of wood fiber for fuel in the period after 1995.

A FOREST RESIDUE SUPPLY SCHEDULE FOR THE STUDY AREA

The supply schedule presented in table 2 represents the probable supply situation a large-volume user of forest residue for energy would face annually in the Libby area for the next 10 years. A "large-volume user" refers to an operation with raw material needs exceeding 20,000 cunits per year. The cost and available volumes presented are based on high-volume, production-oriented, conventional harvesting systems. A supply schedule applicable to small-volume nontypical recovery systems was not developed.

As the schedule indicates, only logging residue appears potentially able to supply large volumes of additional wood fiber in the study area at a reasonable cost. Further, the best logging residue component available for fuel would be the estimated 120,000 to 200,000 cunits available annually through whole-tree logging.

Table 2—Forest residue estimated to be available annually during the period 1986-95, within the defined northwestern Montana operating area[1]

Residue component	Annual volume	Estimated cost
	Thousand cunits	*1984 dollars*
Logging residue		
Volume recovery through whole-tree processing	120-200	25-65/cunit; average 45/cunit
Cull logs and trees from tractor sites	41	65/cunit
Cull logs and trees from cable sites	17	Over 80/cunit
Other forest residue components		
Stand conversion residue		
Slopes to 20 percent	Under 10	Over 65/cunit
Slopes 20-40 percent	Under 20	Over 80/cunit
Backlog slash	Minimal	Over 80/cunit
Selection or salvage logging cull material	Large volumes	Over 80/cunit

[1]Estimates are based on projected harvest levels for the 1986-95 period.

The lower volume estimate represents wood residue available by in-woods processing of whole sawtimber trees. The upper volume figure represents estimated volume available if mill site processing of whole trees is undertaken. The costs of wood fiber available through the two approaches did not differ greatly. Also included in this estimate are 38,000 cunits representing cull portions of the boles of sawtimber trees that could be recovered through whole tree processing.

Crowns and unmerchantable bole tips of sawtimber trees are especially advantageous to energy users. First, they are potentially cheaper than the other components of forest residue; second, there would be little competition from producers of products such as pulp and paper or waferboard who require wood fiber pieces large enough to flake or chip, and have a lower tolerance for bark.

The recoverable volumes and cost of recovery of crowns and unmerchantable bole tips are difficult to accurately estimate. Much of the recovery data used in this analysis are from case studies done in other regions in North America. Consequently, errors of estimation may be greater for this component of the residue resource than for others. Nevertheless, it is the primary source of forest residue in the Libby area that would have the potential to supply a relatively large user at a relatively low cost.

As the material recoverable in whole-tree operations within the supply area is exhausted, the next most promising type of forest residue would be cull logs that could be recovered during sawtimber harvest operations on tractor ground. The volumes of this material in the area appear limited, with about 41,000 cunits of additional material available from all tractor ground in the supply zone, at an estimated cost of $65 per cunit. This estimate includes only logging residue in pieces larger than 4 ft^3 in size. Much greater volumes of smaller pieces would be available, but at much higher costs.

Components of forest residue other than logging residue are far more costly to recover, and offer limited opportunity for a large-volume user. Attention is frequently directed toward the very large volumes of salvage cull material potentially available. In the study area, Forest Service estimates of the volume of dead lodgepole pine not included as stand conversion residue exceed 5 million cunits. Other dead and cull material would increase this figure several times over. In addition to relatively high costs of recovery, however, lack of access and other management constraints on harvesting severely limit the volumes of this material that could be recovered annually in the study area.

COMPETITION FOR WOOD FOR ENERGY

Most of the material that fits into the category of wood fiber residue is technically usable for a variety of products, but is underutilized because of high recovery costs, inaccessibility, and low value. Much of the residue material discussed here as a supply source for energy generation could have multiple uses. As an extreme example, sound dead lodgepole pine 12 inches d.b.h. might be considered a residue in many parts of the Northern Rocky Mountains. This material could produce lumber and other sawn products, veneer logs, house logs, utility poles, pulp and reconstituted board products, as well as home and industrial fuel.

In this section, the value of wood fiber for various competing industrial users in the Inland Empire is examined. It summarizes an analysis reported in greater detail in "The Value of Wood to Competing Users: Energy Versus Product Uses in the Inland Empire" (Keegan and Jackson 1986). The values reported indicate the user's willingness to pay for delivered wood over the long term and are referred to as value use.

Estimating Value Use

Wood is one item in a mix of materials and resources necessary to produce outputs of energy or wood products. The long-run value of wood varies for each user, depending on the value of the product being produced, the rate of return required on capital investments, production costs, and the availability of acceptable substitutes for products such as fuel.

Because of the variability in value of wood to a specific plant, ranges of values were developed to reflect what various energy users and potential competitors could pay over the long term for wood fiber. The estimates were not precise, but rather an indication of whether or not plants or facilities might be expected to purchase wood in competition with other users in the Inland Northwest (fig. 8).

The assumption was made that wood of a quality up to and including material suitable for stud logs and house logs could be part of the wood resource used competitively by fuel or fiber facilities. The potential uses examined were electric power generation, industrial fuel, and the manufacture of pulp, reconstituted boards, posts, poles, rails, studs, and house logs.

Values were estimated based on the following:

- A survey of existing plants where operators were asked what they could pay for wood fiber delivered to the facility and still operate profitably (Keegan and others 1981).
- Historical prices paid or received for various types of wood fiber (Bureau of Business and Economic Research 1977, 1981, 1982; Hawkins 1984).
- Published estimates of capital costs, projected revenues and other operating costs, and published estimates of value use (Forest Industries Magazine 1984; Carroll, Hatch and Associates 1983; EBASCO Services Inc. 1982; Fahey 1980; Flodin 1983; General Electric Company 1982; Jackson and others 1984a; Levi and O'Grady 1980; Pennington 1984; Schuchart and Associates 1980; USDA FS 1978; Withycombe 1974).

Comparative Values of Wood

Table 3 indicates the estimated mill-delivered values for a cunit of wood fiber in the Inland Empire. As indicated, the uses of wood to manufacture a product generally have

Table 3—Estimated value use range for wood utilized for alternative end products in the Inland Empire region

Product or use	Mill-delivered value per cunit
	1984 dollars
Electrical generation	0-25
Industrial fuel to replace	
Coal	25-35
Natural gas	0-65
Fuel oil	0-70
Raw material to produce reconstituted boards	
Particleboard	15-40
Fiberboard	30-80
Waferboard	40-80
Pulp and paper	40-80
Solid products	
Post, rails, poles	50-80
Studs	60-90
House logs	100+

Figure 8—Competition for wood residue is most likely to come from the pulp and reconstituted board products industries.

a higher value than the energy uses. A number of energy uses for wood, however, have value ranges that overlap those of the product uses.

As a substitute for coal, or to generate electricity, wood values generally fall well below those for most manufacturing uses. Exceptions would be low-value manufacturing uses such as particleboard production. It appears, however, that wood could be substituted for fuel oil and natural gas in industrial boilers and be competitive with a number of product uses. The range in values for wood as a substitute for fuel oil or natural gas is large, due primarily to variability in capital costs of wood boiler systems. At the lower end of the capital cost scale, wood as a fuel appears to be competitive with many product uses.

Much of the variation in value for manufacturing products relates to market conditions. Wood as a substitute for natural gas or fuel oil could compete with the particleboard and fiberboard industries under both good and bad wood products markets. During periods of high demand for pulpwood or solid wood products, however, energy producers could very likely have a difficult time competing.

LACK OF COMPETITION IN THE PAST

The Inland Empire has seen virtually no large-scale competition between industrial fuelwood users and manufacturers using wood as a raw material. Competition has been limited primarily because industrial fuelwood users used material that was either not suitable for product uses or was available in quantities much greater than needed. Almost all of the industrial fuelwood needs in the Inland Empire have been met by utilizing the wood fiber residue from the manufacture of lumber and plywood (mill residue). The mill residue components generally used for fuel are bark and fine residue (composed of planer shavings and sawdust). No major manufacturers in the region currently utilize bark as a raw material to produce a product. Planer shavings and sawdust are used as a raw material by particleboard and fiberboard plants, and sawdust is also used by pulp and paper mills. But during years of average and above-average lumber production supplies of these have exceeded fuel and raw material needs (Keegan and Jackson 1985). Because of this surplus, there has been little direct competition between energy users and product users. Low prices for bark and fine residue (currently priced at under $10 per cunit FOB the producer's mill and averaging under $25 per cunit delivered to the user) reflect this lack of competition.

Wood Costs to New Energy Users

As indicated previously, excess mill residue still exists in the region, at least in years of average or above lumber production. A new user, especially in northwestern Montana and northern Idaho, should be able to secure moderate volumes (100,000 cunits of fine residue and bark) for prices well below those indicated in table 3. This situation, however, may prevail only in the near future. The projected excess supply of mill residue for years of average lumber production is small in relation to total supply and demand, with the estimated unutilized volume of fine residue and bark representing less than 10 percent of the total supply (table 1). Therefore, even modest increases in average annual demand for residue (or small decreases in the size of the lumber and plywood industry) would over the long term lead to greater direct competition among users of wood fiber residue and much higher prices for bark and fine residue available at sawmills and plywood plants.

A prospective user of mill residue must also be aware that lumber production varies considerably from year to year, due to volatile lumber markets. Five of the 10 years between 1974 and 1983 were years of below-average lumber and plywood production. Given current demand for mill residue, shortfalls of supply would occur if lumber production dropped to the levels experienced in any of those 5 years (Keegan and Jackson 1985). A recession in wood products as severe as during 1980-82 is unlikely in the next decade, and shortages are not necessarily projected for 5 of the next 10 years, but users should remember that downturns in the lumber markets can occur at any time. Users may be forced in lean years to pay much more for wood fiber, either because competition for mill residue has driven prices up or because they are forced to utilize forest residue.

Both in the near and distant future, new large-volume users of wood for generating energy should be prepared to pay more for wood than was paid in the past for fine mill residue and bark—unless they have firm long-term contracts for mill residue.

ECONOMIC FEASIBILITY OF WOOD-FIRED GENERATORS

The primary focus of the financial analysis is on the use of wood fiber residue to generate electricity. This section summarizes an analysis reported in greater detail in "A Financial Analysis of Generating Electricity From Wood Fuel in Northwestern Montana" (Jackson and others 1984a). A range of types and sizes of wood-fired systems were analyzed in detail to determine the feasibility of producing electricity using wood residue for fuel. Four specific facilities were evaluated—two cogeneration facilities and two stand-alone wood-fired plants. Cogeneration is the generation of process steam, process heat, or space conditioning combined with the generation of electrical power. A stand-alone plant produces electrical power only.

The two cogeneration systems evaluated were a 5-megawatt system and a 15-megawatt system. These represent a range of sizes compatible with the industry in northwestern Montana and the Inland Empire region. A 5-megawatt system could be sustained using the low-value mill residue (bark, planer shavings, and sawdust) generated by a sawmill producing 40 to 60 million bd ft of lumber annually. This would be considered a medium- to large-sized mill in the region. The 15-megawatt facility could be supplied by the bark and fine residue generated by a large mill complex processing in excess of 100 million bd ft of timber, converting approximately 70 percent into lumber and 30 percent into plywood.

Coarse residue could also be used to fuel a power facility. But virtually all coarse residue is being utilized by the pulp and paper industry in the region. Such residue has a value FOB producing mill in excess of $40 per cunit, versus approximately $5 per cunit for bark, planer shavings, and sawdust.

Two stand-alone electrical power-generating facilities were also examined—a 15- and a 25-megawatt facility. These also represent facilities that could be supplied by the wood residue resource in the study area, and are of sufficient size to achieve reasonable economic efficiency.

Capital, Operating, and Maintenance Cost Estimates

Capital costs for both cogeneration and stand-alone wood-fired generating plants were obtained from a computer program written by General Electric Company under contract to the Electric Power Research Institute, Palo Alto, CA. (Computer program and data base available for a fee.) The data base includes both capital costs and operation and maintenance costs for a wide range of sizes and types of plants. The costs are based on feasibility studies done by General Electric and others, and have been carefully validated. They are expressed in 1984 dollars. The installed capital costs for several combinations of mill and generator sizes are shown in table 4.

The proportion of the total cost of a cogeneration system allocated to the generation of electricity is lower than the capital costs shown in table 4. If, for example, a facility such as a sawmill needs a new process steam facility, then the cost of a process steam system alone should be deducted from the total cost of the cogeneration system to determine capital costs applicable to generating electricity. This assumption (that a process steam system was needed) was made in determining the base capital cost to be used in the cogeneration alternatives evaluated in this analysis.

To examine the sensitivity of the financial analysis to changing levels of capital costs, the base capital costs for the four case studies were increased and decreased by 25 percent. A number of sources indicate that the capital costs can be significantly reduced if refurbished equipment (that is, boilers, turbine generators) is substituted for new equipment. These sources indicate the capital costs of a project can be reduced from the indicated \$1.8 to \$2.6 million per megawatt of capacity to approximately \$1 million per megawatt. A separate analysis was consequently done using a capital cost of \$1 million per megawatt.

For all plants, the operating and maintenance costs were assumed to be between 5 and 7 percent of the installed capital costs. These costs include materials and labor to operate the plant, but not fuel.

Fuel Costs

Three levels of wood fiber costs were used in the financial analysis: \$5, \$20, and \$50 per cunit. The \$5 per cunit cost was used to simulate a plant utilizing mill residue generated on site, attaching an opportunity cost about equal to current prices for fine mill residue and bark. It was assumed that the cogeneration facilities (but not the stand-alone facilities) would have the opportunity to acquire wood for \$5 per cunit.

The \$20 per cunit cost was used to represent two situations. The first case is one in which excess mill residue is purchased from sawmills and/or plywood plants at current prices of \$5 per cunit, with a \$15 per cunit allowance for shipping and handling. In the second case, the \$20 per cunit cost illustrates the opportunity cost to mills of utilizing their own mill residue for electrical generation given increases in market prices to \$20 per cunit. The \$50 per cunit cost was used to evaluate the financial feasibility of using forest residue to generate electricity.

Revenues From Electrical Generation

As outlined in the Public Utility Regulatory Policy Act (PURPA) and the Montana State "mini-PURPA" (Administrative Rules of Montana 38.5. 1901-1903), each public utility is obligated to purchase any electrical energy and capacity made available by a qualifying facility. In this analysis, it was assumed that a qualifying facility in northwestern Montana would sell electrical power to Pacific Power and Light Company (PP&L) of Portland, OR.

The Public Service Commission has ruled that three long-term payment options be fixed by law with PP&L. The three options include a completely levelized rate option, an escalating-partially levelized rate option, and an

Table 4—Installed capital costs of wood-fired generators for stand-alone systems, and for cogeneration systems involving mills of various capacities

	Generator size (megawatts)							
Mill size	3	5	7	10	15	20	25	50
	Millions of 1984 dollars							
Stand-alone	—	—	—	25.0	32.1	38.0	44.2	68.0
20-40 million bd ft mill (11,000 lb/h steam)	8.8	14.6	20.5	25.4	—	—	—	—
40-60 million bd ft mill (19,000 lb/h steam)	9.0	15.0	21.0	25.8	—	—	—	—
70-100 million bd ft mill (26,000 lb/h steam)	—	15.3	21.4	26.2	33.2	—	—	—
Mill complex 125 million bd ft lumber 100 million ft^2 plywood (78,000 lb/h steam)	—	—	—	28.9	35.6	41.6	—	—

Source: General Electric Company 1982.

unlevelized rate option. For this analysis the "fully levelized" rate in effect in 1985 was used as the base case, represented by a buyback rate of 6.27 cents per kilowatt hour. The sensitivity of the four options to electricity buyback rates of up to 9.5 cents per kilowatt hour was also analyzed. The two other rate options were also evaluated but were found to be less attractive due to substantially lower initial rates.

Financial Feasibility of Electrical Generation

The traditional approach to capital budgeting as described by Brigham (1979) is the financial model used in this analysis. The method does not explicitly bring the project's financing into the cash flow analysis. As a result, taxable income is overstated, hence taxes are also overstated and the net cash flows from the project are understated. But the cost of capital used to determine the project's Net Present Value (NPV) is adjusted for taxes, and this adjustment largely offsets the understatement of cash flows.

The traditional financial model employed can be simply described as:

Earnings Before Interest
and Taxes − Tax Bill = Net Income
Net Income + Depreciation = Net Cash Flow

The net cash flows from the traditional model are the cash flows available to all investors.

Table 5 provides a summary of the inputs to the model that have just been described. Again, all costs and variables associated with the two cogeneration alternatives (options 1 and 2) are the incremental costs associated with the production of power. It is assumed that the facility (sawmill, plywood plant) needs a new process steam system. Therefore, the costs associated with the process steam system are deducted from the total cost of the cogeneration project.

Both net present value and internal rate of return were calculated for the four case studies, for the various defined levels of capital costs, fuel costs, and revenue rates for electricity. In figures 9 through 12, the net present value is indicated on the y axis for various after-tax discount rates that are indicated on the x axis. The internal rate of return is the discount rate at which the net present value is equal to zero.

A benchmark discount rate of 14.6 percent was chosen. This is the return on equity for the 500 largest manufacturing firms in the United States from 1973 to 1983 (Fortune Magazine 1984). Given the discount rate of 14.6 percent, none of the base capital cost cases (capital costs of $1.8 to $2.6 million per megawatt hour) would be attractive investments at the fully levelized electrical power buyback rate of 6.27 cents per kilowatt hour, even with wood fuel costs of $5 per cunit. When capital costs are reduced by 25 percent, it is only at the lower wood cost levels ($5 per cunit for the 15-megawatt cogeneration case and $20 for the 25-megawatt stand-alone facility), that the internal rate of return at current fully levelized buyback rates exceeds 14.6 percent.

The cost of wood obviously has a substantial impact on the feasibility of wood-fired generating facilities. Reductions in wood cost greatly increase the net present value and internal rate of return. At a $50 per cunit wood cost (representing the cost of forest residue) and current buyback rates, none of the cases offered a positive net present value, even at a 10 percent discount rate. Substantial increases in electrical power buyback rates would be required before forest residue would be an appropriate fuel to generate electricity in generating facilities where new equipment is used.

Table 5—Summary of values and factors used in analyzing the financial feasibility of electrical power generation for four generation facility options

Value/Factor	Option 1: cogeneration (5 MW)	Option 2: cogeneration (15 MW)	Option 3: stand-alone (15 MW)	Option 4: stand-alone (25 MW)
Project life (years)	20	20	20	20
Electrical capacity (MW)	5.0	15.0	15.0	25.0
Electrical generation (million kWh)	40.3	120.9	120.9	201.6
Capital cost allocated to electrical generation (millions 1984 dollars)	13.3	30.6	32.1	44.2
Investment tax credit (percent)	10	10	10	10
Depreciation method	- - - - - - - - Accelerated cost recovery system - - - - - - - -			
First year operating and maintenance costs (millions 1984 dollars)	0.8	1.6	1.7	2.2
Fuel consumed to generate electricity (cunits)	24,170	68,030	84,620	141,040
Growth rate of operating and maintenance costs and fuel costs (percent)	5	5	5	5
PURPA buyback option	- - - - - - Fully levelized fixed rate (6.27 cents/kWh) - - - - - -			
Tax rate (percent)	46	46	46	46

Source: General Electric Company 1982. All costs and factors associated with cogeneration facilities (options 1 and 2) are the incremental costs associated with the production of power, in excess of costs of the process steam facility.

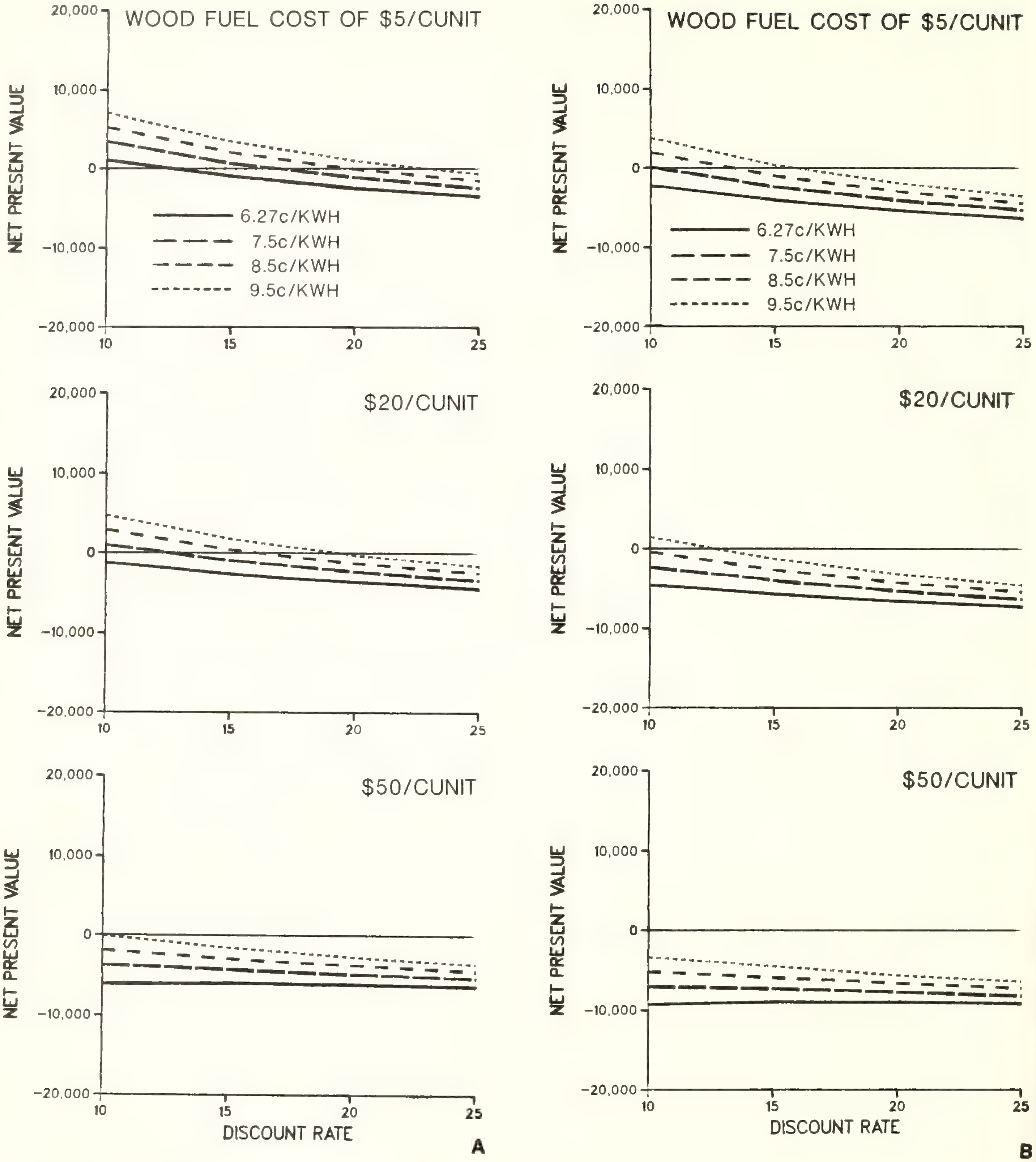


Figure 9—(A) Net present value at various discount rates for a 5-megawatt cogeneration facility—capital cost $9.97 million (1984 dollars). (B) Net present value at various discount rates for a 5-megawatt cogeneration facility—capital cost $13.3 million (1984 dollars). (C) Net present value at various discount rates for a 5-megawatt cogeneration facility—capital cost $16.6 million (1984 dollars).

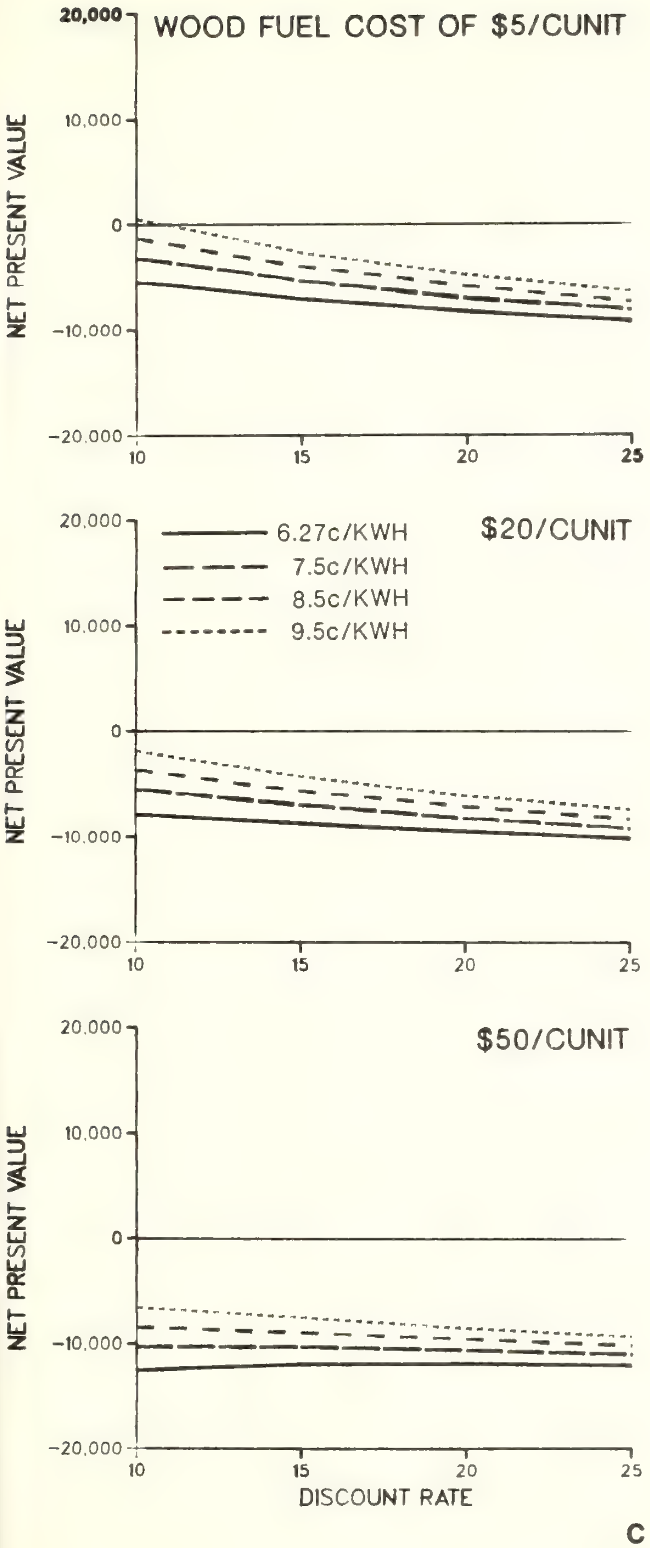

WOOD FUEL COST OF $5/CUNIT
NET PRESENT VALUE
20,000
10,000
0
-10,000
-20,000
10
15
20
25
6.27c/KWH
7.5c/KWH
8.5c/KWH
9.5c/KWH
$20/CUNIT
$50/CUNIT
DISCOUNT RATE
C

Figure 9—(Con.)

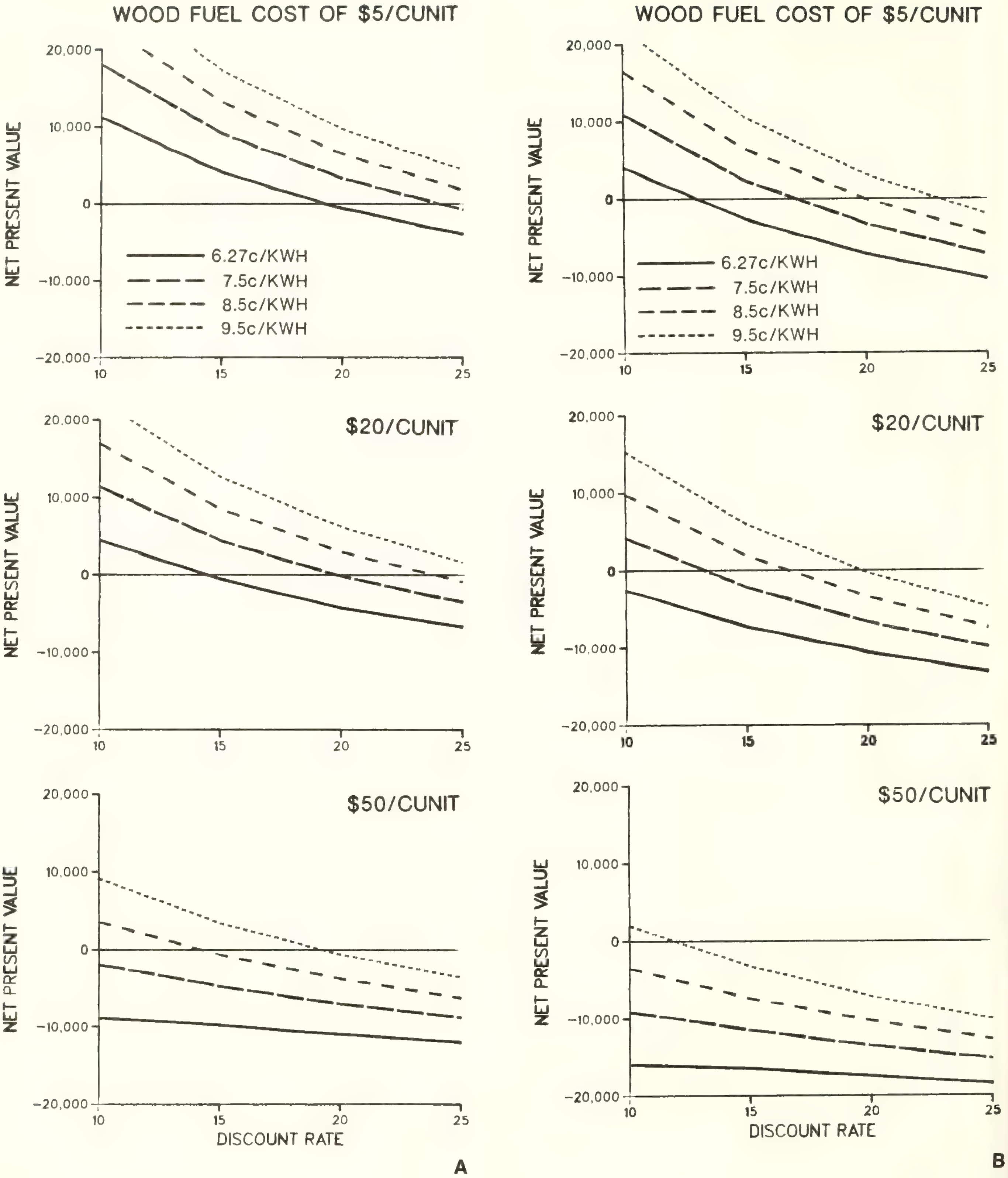


Figure 10—(A) Net present value at various discount rates for a 15-megawatt cogeneration facility—capital cost $22.9 million (1984 dollars). (B) Net present value at various discount rates for a 15-megawatt cogeneration facility—capital cost $30.6 million (1984 dollars). (C) Net present value at various discount rates for a 15-megawatt cogeneration facility—capital cost $38.2 million (1984 dollars).

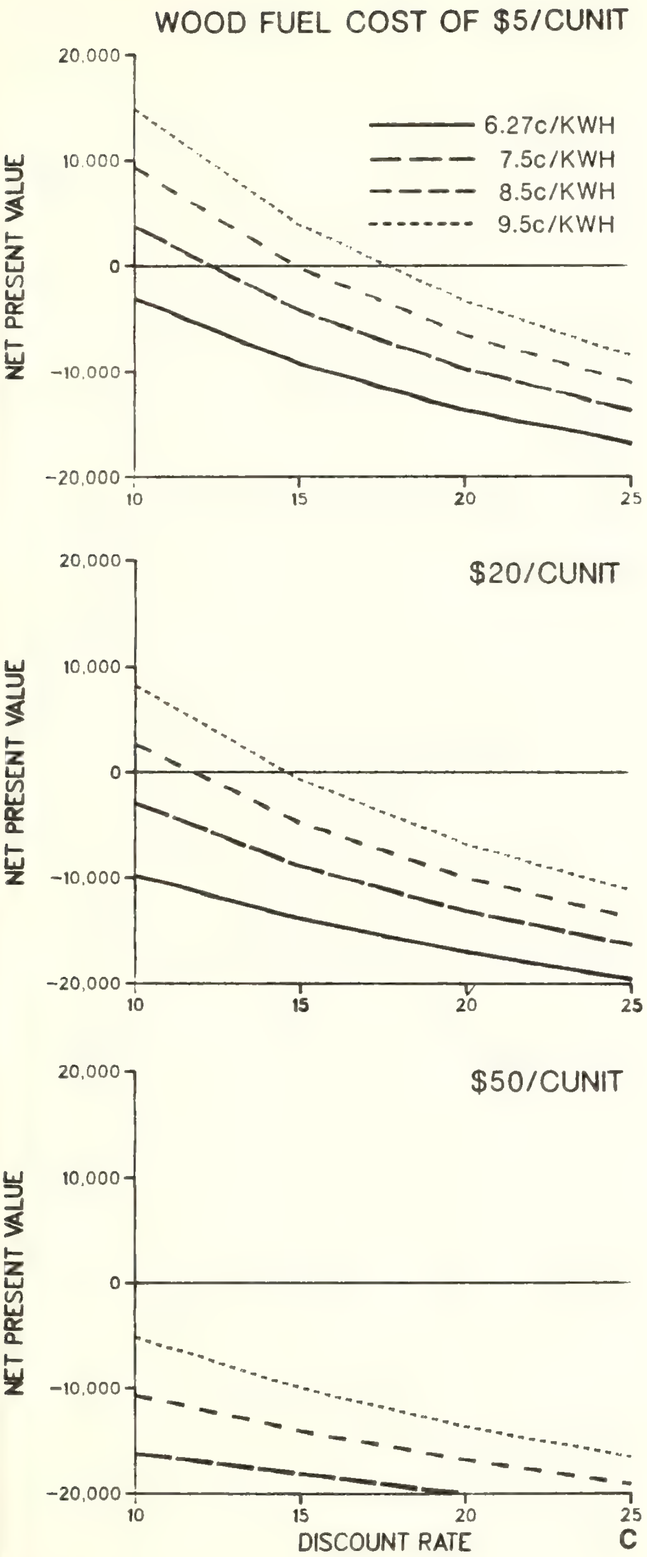


Figure 10—(Con.)

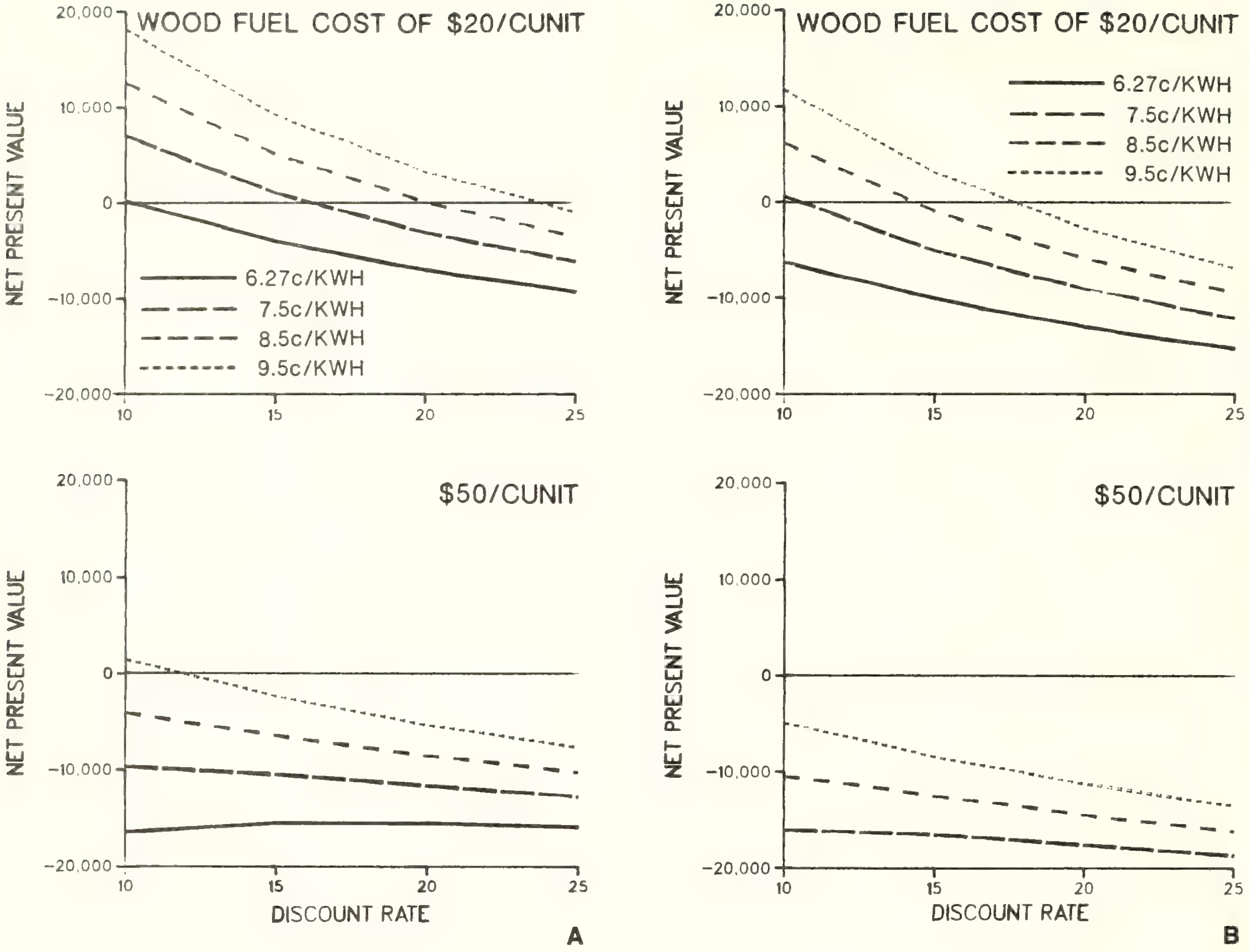


Figure 11—(A) Net present value at various discount rates for a 15-megawatt stand-alone facility—capital cost $24.1 million (1984 dollars). (B) Net present value at various discount rates for a 15-megawatt stand-alone facility—capital cost $32.1 million (1984 dollars). (C) Net present value at various discount rates for a 15-megawatt stand-alone facility—capital cost $40.1 million (1984 dollars).

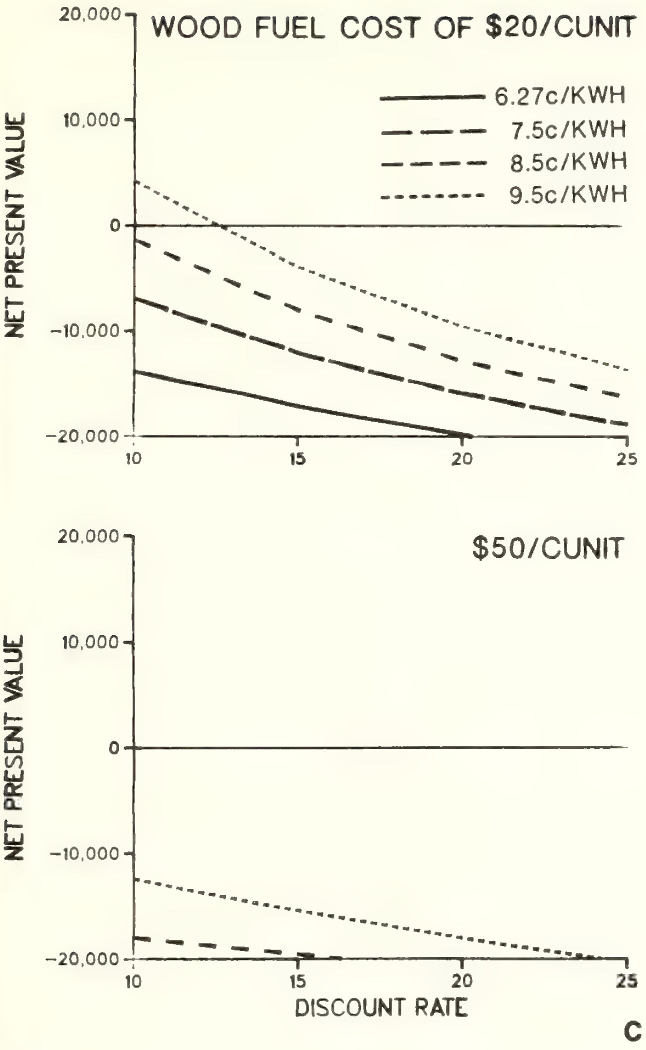


Figure 11—(Con.)

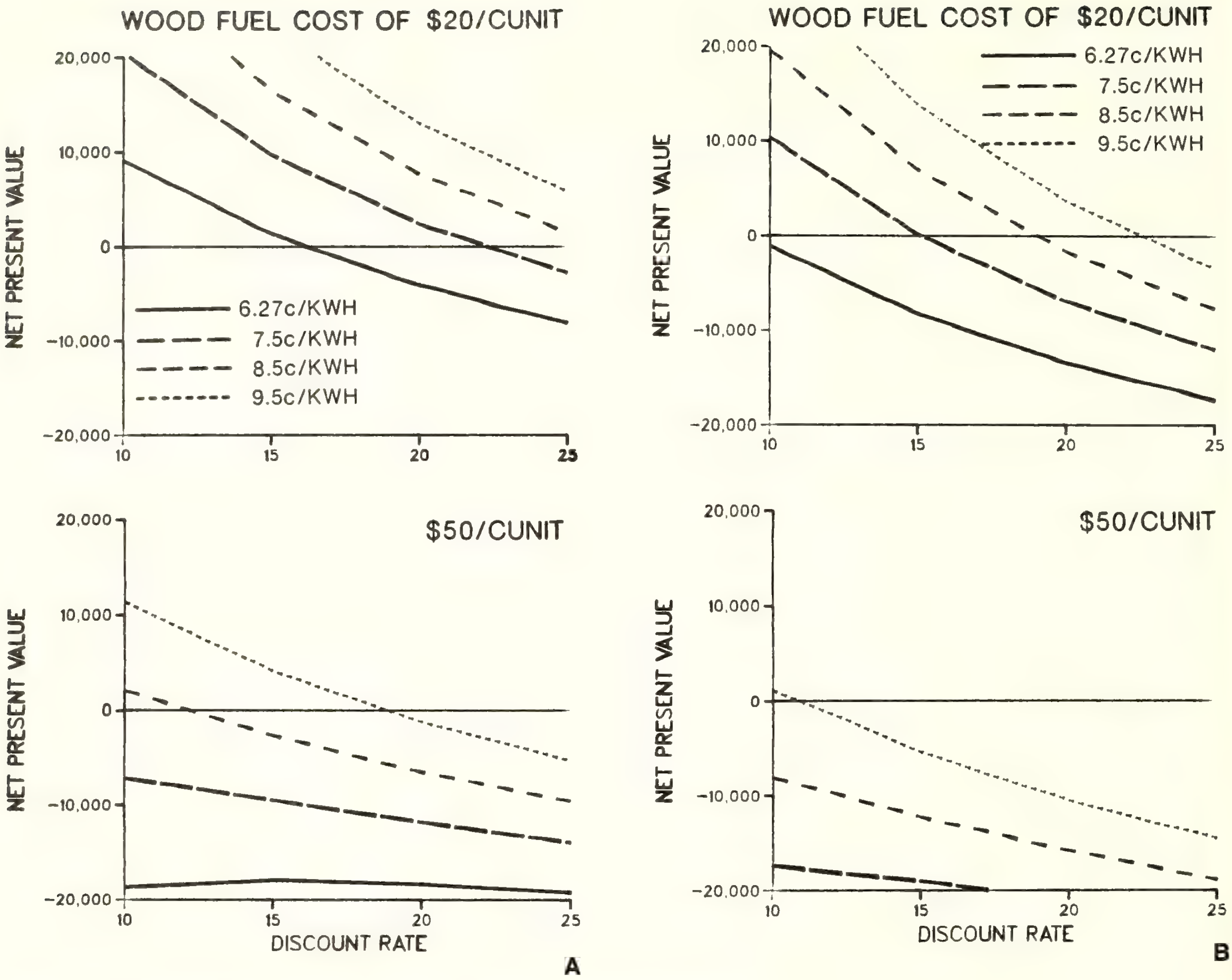
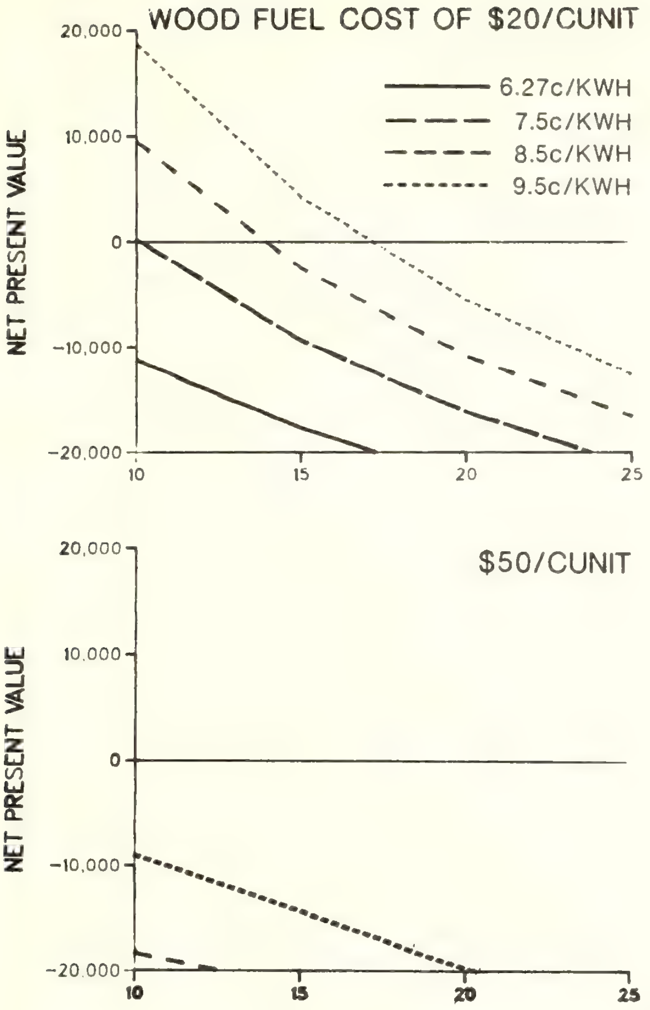


Figure 12—(A) Net present value at various discount rates for a 25-megawatt stand-alone facility—capital cost $33.2 million (1984 dollars). (B) Net present value at various discount rates for a 25-megawatt stand-alone facility—capital cost $44.2 million (1984 dollars). (C) Net present value at various discount rates for a 25-megawatt stand-alone facility—capital cost $55.2 million (1984 dollars).



C

Figure 12—(Con.)

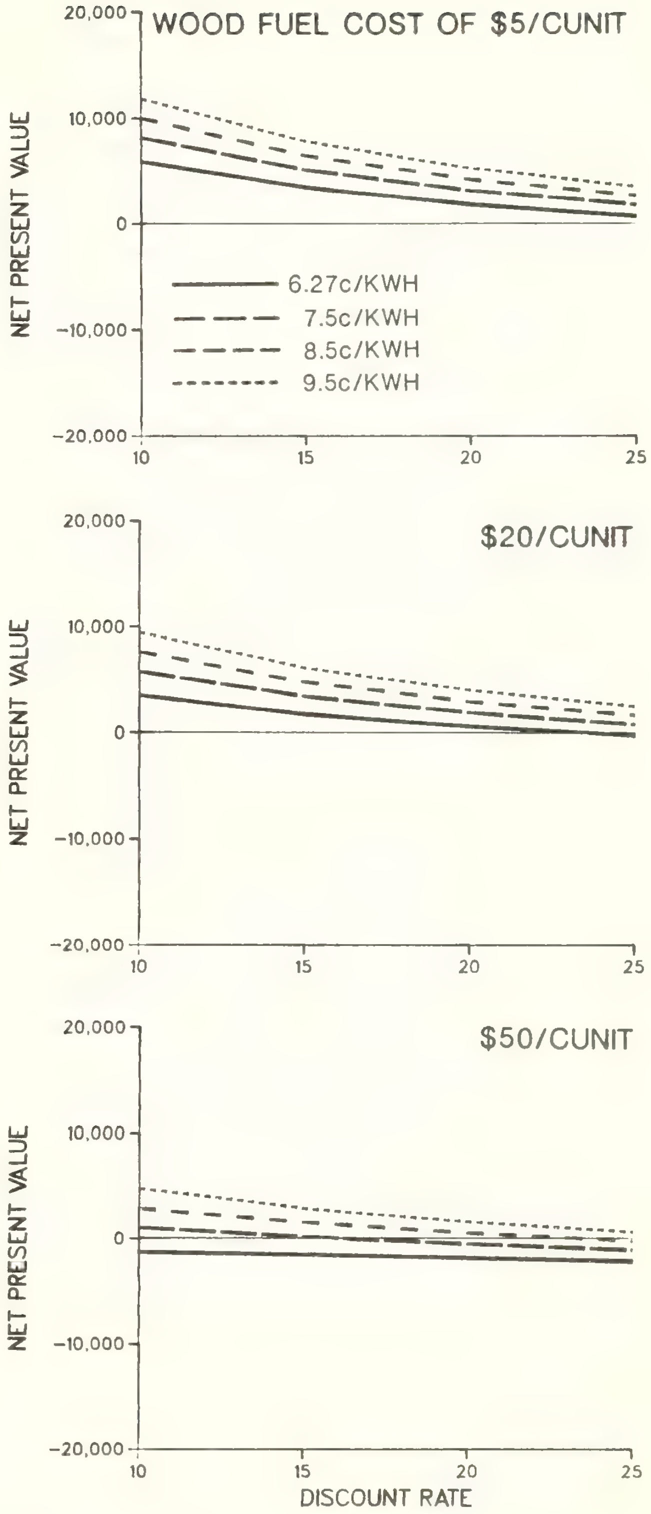


Figure 13—Net present value at various discount rates for a 5-megawatt cogeneration facility with capital costs of I million dollars per megawatt of capacity.

Reducing capital costs to $1 million per megawatt of capacity, through the use of refurbished equipment, can make the generation of electricity from wood considerably more attractive. Figure 13 indicates the net present value for various discount rates for a cogeneration facility of 5 megawatt capacity, with capital costs of $1 million per megawatt. At wood costs of $5 per cunit, a cogeneration facility would offer an attractive investment, with an estimated rate of return of over 25 percent, given current buyback rates. At $20 per cunit at current buyback rates, the facility would still offer a rate of return of over 20 percent. Even at the much lower capital costs of $1 million per megawatt, however, forest residue at $50 per cunit does not appear to be feasible.

WOOD AS A SUBSTITUTE FUEL FOR NATURAL GAS AND FUEL OIL IN PROCESS STEAM BOILERS

The cost per Btu of natural gas or fuel oil indicates that in northwestern Montana relatively high costs could be paid for wood as a substitute fuel. Given systems that had equal capital and operating expenses, wood systems could absorb a fuel cost in excess of $80 per cunit and compete with natural gas or number 2 fuel oil (table 6). The analysis summarized in table 6 was based on fuel oil and natural gas prices in effect in 1984-85. Declines in the cost of these fuels in 1986 obviously make the substitution of wood at least temporarily less attractive than the analysis indicates. Wood appears to offer potential, however, and should be evaluated on a case-by-case basis.

Capital costs of wood systems are generally considerably higher than those for natural gas or fuel oil. The feasibility of developing wood-fired systems consequently depends on whether reductions in fuel costs will offset increased capital and operating costs. A financial analysis of two wood-fired process steam systems was done to examine this relationship. The analysis summarized here is reported in greater detail in "An Examination of the Financial Feasibility of Substituting Wood for Fuel Oil and Natural Gas in Northwestern Montana" (Keegan and Jackson 1984).

Variations in Capital Costs

Capital costs of wood systems relative to fuel oil and natural gas systems are subject to tremendous variation. One source indicates that new wood systems cost from 2.5 to 7 times as much as the fossil fuel systems (Levi and O'Grady 1980). Additionally, inherent variation in utilization of system capacity can have significant impacts on total system costs. Process steam boilers are used by many different kinds of facilities, including institutions such as schools using steam primarily for winter heat and manufacturers such as sawmills that use steam heat to dry lumber. Some of these facilities require boiler systems with a capacity far in excess of their average steam needs throughout the year. Obviously, if a system is designed primarily to heat a building, the winter load is much greater than the summer load. It is not uncommon for boiler systems to be built at more than twice the average hourly steam need. Variation of this magnitude in utilization of capacity can have a tremendous impact on the financial feasibility of the system.

Because of these characteristics, the financial feasibility of two systems representing "high" and "low" capital costs relative to comparable fossil fuel systems was examined at two levels of capacity utilization. Procedures and assumptions adopted for the analysis were:

- The analysis examined two boiler systems: one with a capacity of 20,000 lb/h and one with a capacity of 80,000 lb/h.
- Operating levels of 80 percent and 40 percent of capacity were examined for each system.
- A 15-year useful life was assumed.
- New wood-fired systems were compared with new fuel oil or natural gas systems, assuming no previous steam system was in place.
- The costs used in the financial analysis were the excess capital and operating costs of the wood system over the fossil fuel system. The benefits were the reduced fuel costs per Btu, if any, resulting from using wood.
- It was assumed that firms would use the investment tax credit in the first year, and that the tax rate on income would be the corporate rate of 46 percent.
- The financial model used was the traditional approach to capital budgeting described by Brigham (1979). The accelerated cost recovery system method of depreciation was used.
- Capital costs for the systems being compared were assumed to be:

80,000-pound system

	Million $
Wood	5.8
(2.5 × gas:2.25 × oil)	
Fuel oil	2.6
Gas	2.3

(General Electric Company 1982; Schuchart & Associates 1980)

Table 6—A comparison of the cost of energy derived from fossil fuels and from wood at alternative procurement costs

Fuel	Assumed cost per unit	Assumed combustion efficiency	Est. high heating value (Btu's per unit)	Calculated dollars per million Btu's[1]
	Dollars	*Percent*	*Btu's*	*Dollars*
Fuel oil	0.75/gal	0.86	150,000	5.81
Natural gas	.0045/ft^3	.79	1,035	5.50
Coal	20.00/ton	.85	17,200,000	1.38
Wood fuel	5.00/cunit	.65	22,500,000	.34
Wood fuel	20.00/cunit	.65	22,500,000	1.36
Wood fuel	50.00/cunit	.65	22,500,000	3.42
Wood fuel	80.00/cunit	.65	22,500,000	5.47

[1]Dollars/million Btu's = cost per unit ÷ [(high heating value × combustion efficiency) ÷ 1,000,000].

20,000-pound system

	Million $
Wood	2.3
	(3.4 × gas)
Fuel oil	0.75
Gas	0.667

(Lin 1983; Rafferty 1984)

- Operating costs for the first year were as follows:
  80,000-pound system:
  Wood $345,000
  Fuel oil 184,000
  Gas 184,000
  20,000-pound system:
  Wood $135,000
  Fuel oil 75,000
  Gas 75,000
- Fuel costs used were $4.50 per thousand ft^3 for natural gas and $0.75 per gallon for fuel oil.
- Wood costs ranging up to $75 per cunit were examined.
- Operating and fuel costs were increased at the rate of 5 percent per year. The escalation rate for operating and fuel costs is the forecasted average annual implicit price deflator for the years 1983-2003 by Chase Econometrics in their U.S. Macroeconomic Long-Term Forecasts, Third Quarter 1984.

Financial Feasibility of the Two Systems

The analyses indicate that the feasibility of utilizing wood systems in place of natural gas or fuel oil is tremendously variable, as is the associated value of wood as a fuel. Examining the larger system (80,000 lb/h capacity of process steam) at the high level of capacity utilization, the system appears feasible even at relatively high wood costs. Figure 14 indicates the rate of return and net present value of an investment in wood systems in place of natural gas or fuel oil for the 80,000 lb/h system. Analyses for wood costs of $25, $50, and $75 per cunit are indicated.

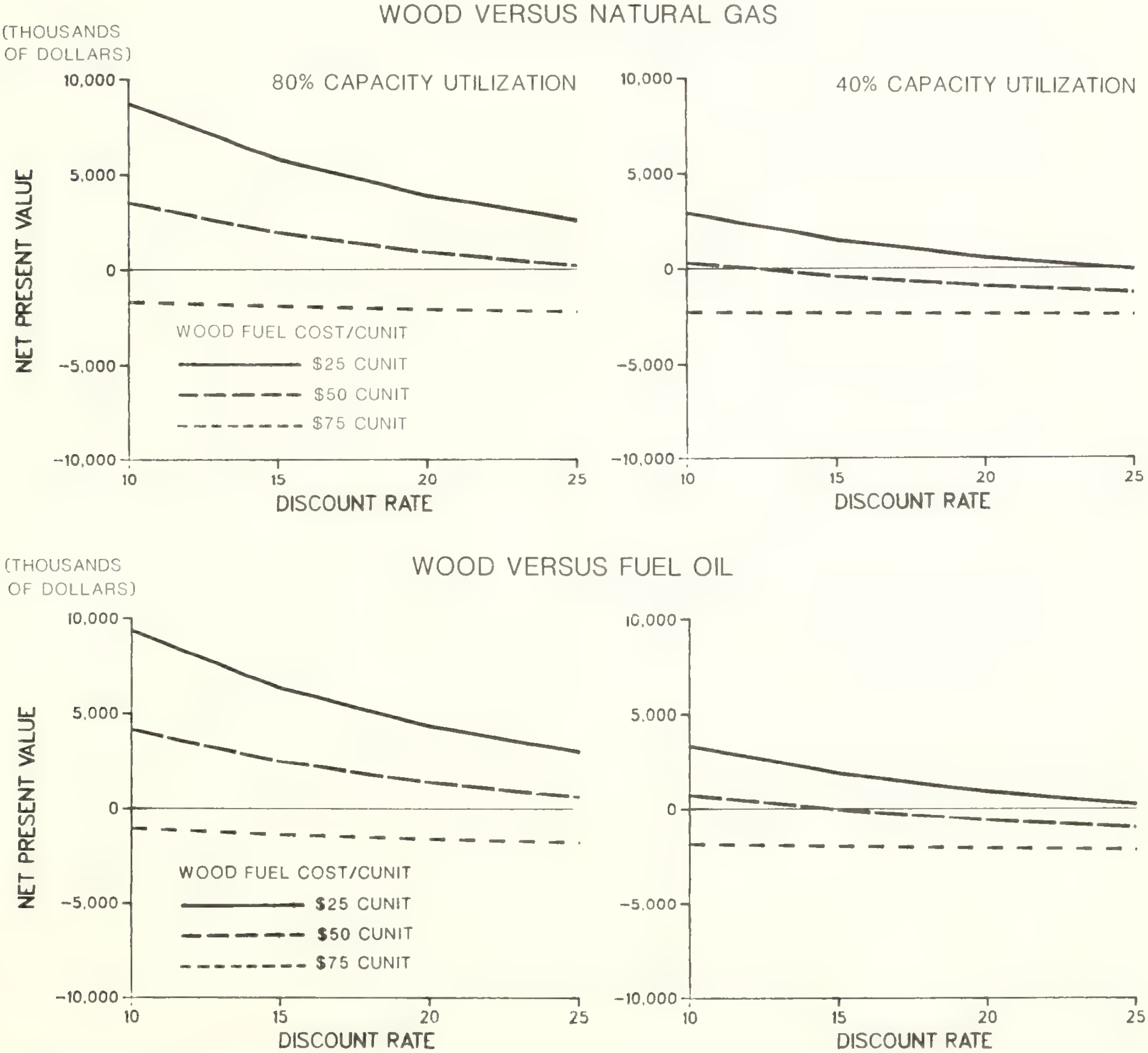


Figure 14—Net present value of an investment in wood-fired systems in place of natural gas or fuel-oil-fired systems—80,000 lb/h industrial boiler system at two levels of utilization.

At wood costs of $50 per cunit the substitution of wood for fossil fuels would appear to be a very attractive investment where capital costs are no more than 2.25 to 2.5 times those for the natural gas or fuel oil systems. As expected, when capacity utilization of 40 percent is assumed, the price a facility could pay for wood and still earn an adequate return is reduced. The rate of return after taxes would be 13 to 15 percent given $50 per cunit wood costs.

As the capital costs of wood systems increase relative to the two fossil fuel systems, the financial attractiveness is reduced. The second-sized facility evaluated was considerably smaller—20,000 lb/h capacity. The cost of the smaller system was higher relative to the fossil fuel systems—approximately 3.4 times higher, compared to a ratio of about 2.5 for the larger system. At an 80 percent utilization of capacity, this wood system appears to offer an after-tax rate of return of about 15 percent, at wood costs of $50 per cunit (fig. 15). When wood costs of $25 per cunit were assumed, the rate of return—over 25 percent—certainly makes the project feasible as a substitute for both natural gas and fuel oil. At a capacity utilization level of 40 percent, the smaller wood system appears to offer an adequate rate of return only at very low wood costs. At $25 per cunit the after-tax return is about 12 percent.

A wood system with capital costs seven times the capital investment for a comparable oil and gas system, as indicated by Levi and O'Grady (1980), would probably not be an attractive investment even if the wood were free.

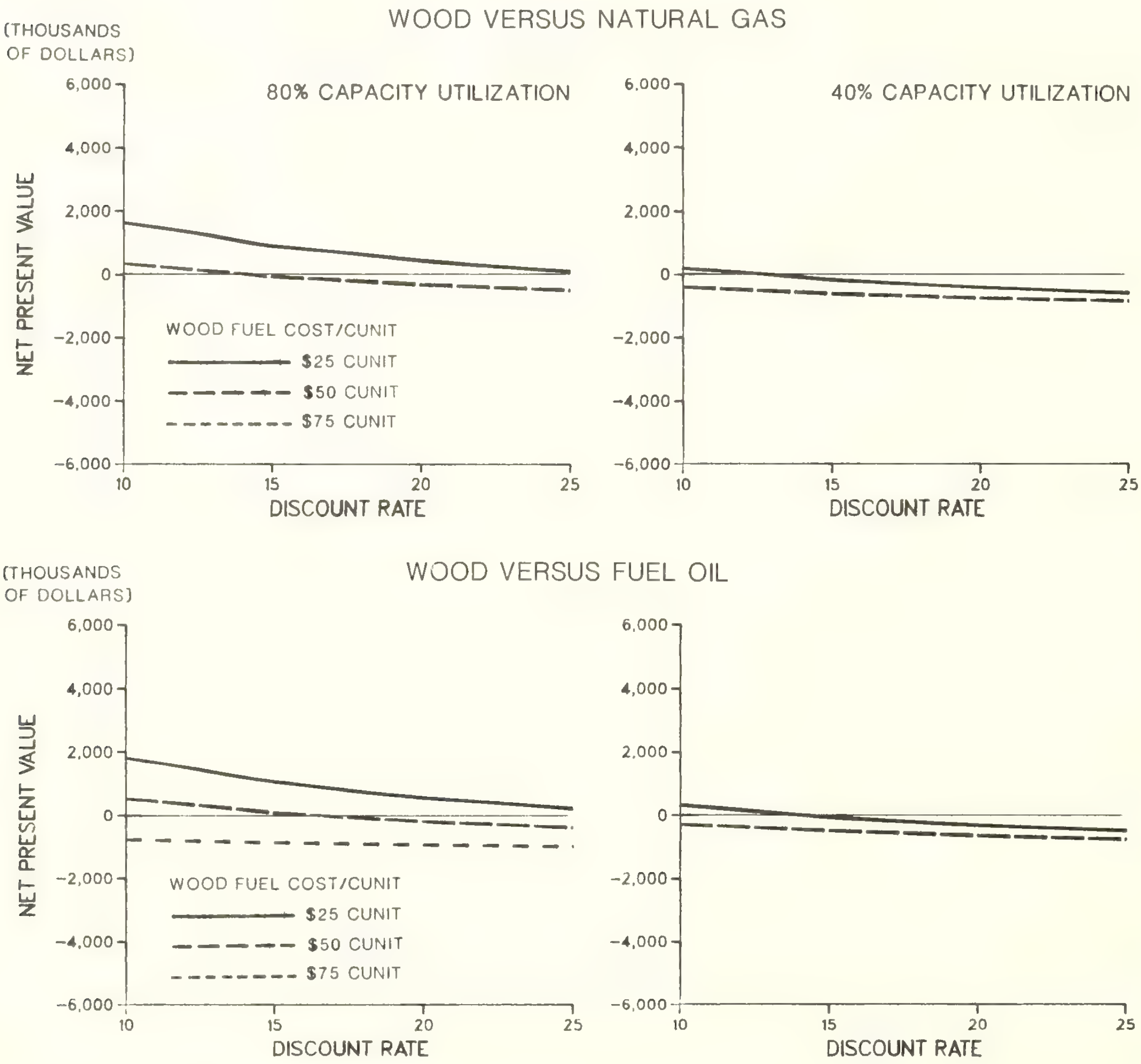


Figure 15—Net present value of an investment in wood-fired systems in place of natural gas or fuel-oil-fired systems—20,000 lb/h industrial boiler system at two levels of utilization.

WOOD VERSUS NATURAL GAS OR FUEL OIL

The analysis described above indicates that under certain circumstances the wood systems are more financially attractive than fuel oil or natural gas systems and that they can support relatively high wood costs. In fact, if capital costs of the wood systems are only 2 to 2.5 times those for the two fossil fuels and the facility will operate at a relatively high rate of capacity utilization, wood costs in excess of $50 per cunit could be borne. This should make forest residue a feasible substitute fuel.

At the same time, there are a number of complicating factors for a firm to consider. First, there is tremendous variation in capital costs and capacity utilization. The 80,000-pound system evaluated is larger than that required by most steam users in the area. A 20,000-pound system is more in line with the needs of many of the potential users. These smaller systems can incur much higher relative capital costs for wood systems. Seasonal variation in needs also greatly reduces capacity utilization for many users. At significantly higher relative capital costs and low capacity utilization, wood systems may not be feasible even if wood were free.

There are also some inconveniences and disadvantages associated with wood use which were not incorporated into the financial analysis. These include the relatively large area needed to store wood fuel, increased fire hazard, slower boiler response times, increased heavy truck traffic, and pungent odor from large volumes of chipped or hogged wood. There have been instances in the region where conversions from fuel oil to wood were not undertaken because of one or more of these disadvantages.

Because many facilities already have fuel oil or natural gas systems, the prospect of replacing the existing system further complicates the overall picture. The choice of a wood system and the value of wood as a fuel in place of fuel oil or natural gas must be handled on a case-by-case basis. The analysis does establish, however, that wood can be used in place of these two fossil fuels and it can have a relatively high value (up to $70 per cunit) as a fuel replacement, especially for larger systems at a high level of capacity utilization.

BARRIERS TO INCREASED RESIDUE UTILIZATION

The major focus of this project was on the volumes of wood fiber residue available at various prices and the financial feasibility of using wood fiber residue in energy facilities. Based on these analyses, the utilization of wood fiber for energy in Montana appears to be constrained primarily by the cost of recovery and/or the revenue from the sale of energy (or the dollars saved substituting wood for other fuels). Additional barriers to residue utilization in the area include a complex permitting and siting process, shorter contract periods for timber than for fossil fuels, and various environmental concerns of the landowners and managers.

The major noneconomic barrier to the increased utilization of wood residue for energy is a complex and poorly defined permitting process. In response to this situation, the Montana Department of Natural Resources is developing a handbook to simplify the process of establishing bioenergy facilities in Montana. The Bonneville Power Administration is initiating the development of a similar document covering the entire Northwest.

The most available component of the forest residue resource—logging residue—can be removed efficiently only in conjunction with sawtimber harvest operations. The typical sawtimber sale extends no longer than 5 years, much shorter than the supply contract period commonly entered into for coal. These short-term timber sales can be attributed to land management, budgetary, and legislative constraints, as well as volatile and uncertain markets for wood products. Given the poor economic outlook for wood energy, promoting increased utilization of wood for energy would not in itself be a compelling argument for extending the length of timber sales.

Regardless of short-term timber sales, it is possible to obtain longer term assurances of forest residue. The large mills near Libby, MT, for example, have been operating for up to 50 years on the same site. Large investments are currently being made in lumber processing facilities, therefore a major forest products industry will exist in the area far into the future. An energy facility could certainly enter into long-term contracts for logging residue with both mills and loggers who purchase timber. In addition, some components of forest residue, such as stand conversion residue, for which there is no market, would be available on longer term contracts of up to 10 years.

Periodically, the prospect of adverse environmental impacts on the site is raised as a constraint on intensive residue recovery. Although levels of utilization, even for fuel, are usually not extreme enough to create impacts, the functions of woody residue in the ecosystem should not be ignored. Intensive wood utilization influences many factors, from microbiological functions to esthetic quality. Some effects, such as fuels reduction, elimination of unsightly residue concentrations, and elimination of physical barriers to management activities, are generally desirable. The potential for adverse impacts exists when the quantity and type of residue material remaining on the site will no longer satisfy the immediate and long-term needs of the ecosystem.

Physically, residue provides ground cover that moderates temperature fluctuations, conserves soil moisture by reducing evaporation, and creates microsites favorable to seed germination (fig. 16). Mechanically, residue provides shade and wind barriers for sensitive seedlings, protects small trees from snow loads, and reduces damage from grazing or browsing animals. Residue remaining on site reduces soil erosion and sedimentation, which can be severe on logged areas. Residue is also essential to wildlife habitat.

Biologically, residue provides the principal energy source for the microbiological processes critical to soil development and plant nutrition. Major processes include nutrient release from organic material through decay processes, fixation of atmospheric nitrogen, and support of ectomycorrhizal fungi.

The potential impacts of intensive residue utilization vary with site conditions, silvicultural prescriptions, and harvesting systems. The highest probability of adverse impact occurs where very intensive levels of utilization are applied in clearcut units, especially in combination with

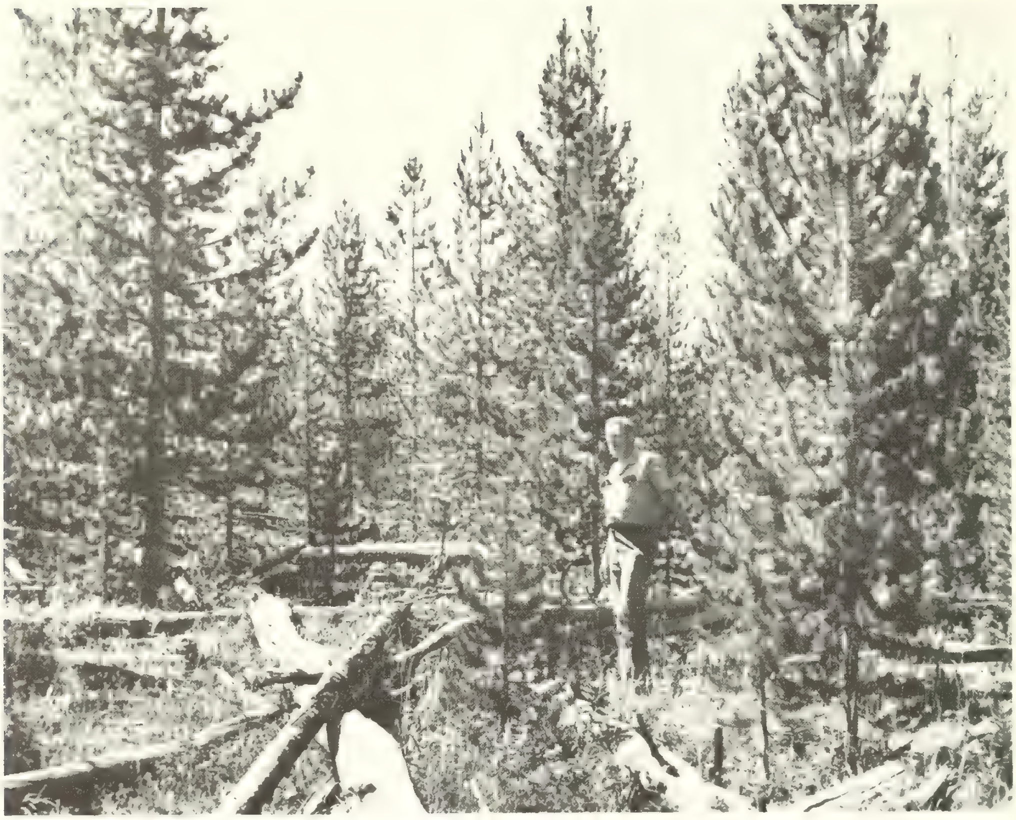


Figure 16—Residues left on site provide many benefits—moderating temperatures, reducing soil moisture loss, creating favorable microsites for seed germination, and nutrients.

severe physiographic conditions. Harvesting systems designed to remove and process whole trees, as many "small-stem" systems do, can be of particular concern because little or no woody residue remains on site.

Given the integral role and function of wood residue in the forest ecosystem, land managers need to assess each situation independently. Decisions regarding utilization level can then be made in a manner that will avoid—or at least greatly reduce—the probability of severe adverse environmental impacts.

HIGHLIGHTS AND CONCLUSIONS

Two sources of wood residue in northwestern Montana—mill residue and logging residue—appear to offer potential for supplying relatively large-volume facilities using wood to generate energy. Unutilized mill residue from the manufacture of logs into lumber and plywood is the cheapest potential source. At present, slightly more than 100,000 cunits of unutilized mill residue should be available annually in the designated supply area, in years of average or above lumber production. Delivered costs for this material are presently relatively low, ranging from $10 to $30 per cunit.

If a plant required the entire 100,000 cunits of unutilized mill residue, however, it would probably be necessary to sharply curtail operations or rely heavily on forest residue during periods of below-average lumber production and mill residue availability. In addition, the unutilized volume represents only a very small percentage of the total supply of mill residue in the Inland Empire region. Consequently, a relatively small increase in demand or a small decline in total sawmill capacity could immediately eliminate the excess and lead to a significant price increase.

Relatively large volumes of logging residue are available annually in the supply area. Based on an inventory of recently logged sites, however, it is apparent that utilization of large cull and dead material on timber sale areas is already at a high level. Volumes of large, relatively sound wood fiber remaining on site are limited. The crowns and unmerchantable bole tips of sawtimber trees offer the greatest potential for supplying a large-volume residue user. An estimated 120,000 to 200,000 cunits should be available annually in the supply area through logging systems designed to recover top and limb wood from the sawtimber harvest. This material would have an estimated cost delivered and chipped or hogged of approximately $45 per cunit. There should be virtually no competition with product manufacturers for this component of the residue resource.

The generation of electricity from wood in northwestern Montana appears feasible only given optimum conditions that would include very low wood costs and low capital costs. The use of higher cost forest residue to generate electricity does not appear feasible unless very large increases in buyback rates develop. This seems highly unlikely in the near future. The use of wood as a substi-

tute fuel for coal would also have a relatively low value and could not be expected to support the costs necessary to recover forest residue.

An analysis indicates that as a substitute for fuel oil or natural gas wood residue can support relatively high costs. Under conditions of relatively low capital costs for wood-fired systems and a high degree of capacity utilization, wood costs up to $70 per cunit could be borne. Some components of forest residue would certainly be available at this price. But there is tremendous variation in capital costs of wood systems and in the degree of capacity utilization. Systems with high capital costs and/or low capacity utilization may not be feasible even if wood were free.

The major barriers to increased residue utilization in the Inland Empire are economic. A number of noneconomic factors such as complex permitting and siting regulations and land management and environmental concerns also influence utilization. At present, however, these do not represent critical barriers and State and Federal agencies in the region are actively involved in programs to eliminate unnecessary constraints.

The Outlook for Wood Residue as an Energy Source

Wood fiber currently is an important source of energy throughout northwestern Montana as well as in the entire Inland Empire region. In the past 20 years, and especially in the last 10 years, large-scale use of wood for energy has developed. In the near future, however, only limited additional wood energy development is likely to occur in the region. This is primarily because electrical power buyback rates, which are presently relatively low, will probably be recalculated and lowered further due to a surplus of generating capacity throughout the Northwest. Additionally, natural gas and fuel oil prices have declined slightly and may decline further in the next few years.

In the longer term, the contribution of wood to the region's energy needs should continue to expand, primarily through the development of cogeneration projects by wood products manufacturers in the region. It is unclear, however, when new increments of power will be needed in the Northwest. The Northwest Power Planning Council's Regional Plan calls for wood-fueled cogeneration systems to supply as much as 400 megawatts of additional electrical power in the Northwest in the next 20 years. The plan is being revised, and it appears that power surpluses may exist in the region for 15 to 20 years. At whatever point in time the region needs new increments of power, wood residue can make a significant contribution.

Of the various types of wood residue available, mill residue has been virtually the only source of wood fuel used to generate electricity in the Inland Empire, and unutilized volumes can support some expansion of cogeneration capacity. A significant expansion, however, would have to be based on a mix of mill and forest residue to avoid disrupting the supply of wood fiber to manufacturing plants.

This situation points to two areas requiring further study in the Inland Empire. These are (1) a detailed analysis of the potential of the wood products industry to supply additional increments of power, and the potential impact of this on other users of wood fiber residue in the region; and (2) continuing development and evaluation of more efficient forest residue recovery systems.

REFERENCES

Brigham, Eugene F. Financial management: theory and practice. 2d ed. Hinsdale, IL: The Dryden Press; 1979; chapter 11.

Brown, James K.; Snell, J. A. Kendall; Bunnell, David L. Handbook for predicting slash weight of western conifers. General Technical Report INT-37. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 37 p.

Bureau of Business and Economic Research. 1976 Montana forest industries data collection system. 1977. Unpublished data base on file at: University of Montana, Bureau of Business and Economic Research, Missoula, MT.

Bureau of Business and Economic Research. 1979 Idaho forest industries data collection system. 1981. Unpublished data base on file at: University of Montana, Bureau of Business and Economic Research, Missoula, MT.

Bureau of Business and Economic Research. 1981 Montana forest industries data collection system. 1982. Unpublished data base on file at: University of Montana, Bureau of Business and Economic Research, Missoula, MT.

Carrol, Hatch, and Associates. Feasibility study for Avison Lumber Company, Molalla, OR on building and operating a wood fueled power generating plant. 1983. Unpublished report on file at: Oregon Department of Energy, Portland, OR. Not consecutively numbered.

Cody, Harold M. Potlatch's new tissue machine at Lewiston adds 50,000 TPY capacity. Pulp and Paper. 54(13): 88-91; 1980.

EBASCO Services Incorporated. Hulett, WY wood waste to electricity feasibility study. 1982. Unpublished report on file at: EBASCO Services Incorporated, Bellevue, WA. [Conducted for Wyoming State Forestry Division, Cheyenne, WY.] Not consecutively numbered.

Fahey, Thomas D. Evaluating dead lodgepole pine for products. Forest Products Journal. 30(12): 34-39; 1980.

Faurot, James L. Estimating merchantable volume and stem residue in four timber species. Research Paper INT-196. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 55 p.

Flodin Lumber and Manufacturing Company. A three megawatt biomass-fired cogeneration plant feasibility study. 1983. Unpublished report on file at: Montana Department of Natural Resources, Helena, MT. 113 p.

Forest Products Journal. Potlatch strives for energy self-sufficiency. Forest Products Journal. 32(1): 58; 1982.

Forest Industries Magazine. MDF's new state of the art. Forest Industries Magazine. 111(8): 49; 1984.

Fortune Magazine. Who did best and worst among the 500: total return to investors, 1973-83. Fortune Magazine. 1984 April 30: 296.

General Electric Company. Dual energy use systems (DEUS) computer evaluation model and manuals, EPRI EM-2776, 1982. Volumes 1 and 2. Palo Alto, CA: Electric Power Research Institute.

Hawkins, Charles. 1984. Unpublished data on file at: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory, Missoula, MT.

Hedin, I. B. Comparison of two logging systems in interior British Columbia: central processing yard vs. conventional. Technical Report No. TR-45. Vancouver, BC: Forest Engineering Research Institute of Canada; 1980. 53 p.

Howard, James O.; Fiedler, Carl E. Estimators and characteristics of logging residue in Montana. Research Paper PNW-321. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1984. 29 p.

Jackson, Timothy P.; Keegan, Charles E.; Withycombe, Richard P. A financial analysis of generating electricity from wood fuel in northwestern Montana. 1984a. Unpublished paper on file at: Bureau of Business and Economic Research, University of Montana, Missoula, MT. 25 p.

Jackson, Timothy P.; Withycombe, Richard P.; Keegan, Charles E. Estimating the costs of recovering forest residue in the Northern Rocky Mountains. Missoula, MT: Bureau of Business and Economic Research, University of Montana; 1984b. 18 p.

Keegan, Charles E. The cost and availability of forest residue in the Northern Rocky Mountains. Missoula, MT: Bureau of Business and Economic Research, University of Montana; 1981. 51 p.

Keegan, Charles E.; Jackson, Timothy P. An examination of the financial feasibility of substituting wood for fuel oil and natural gas in northwestern Montana. 1984. Unpublished report on file at: Bureau of Business and Economic Research, University of Montana, Missoula, MT. 8 p.

Keegan, Charles E.; Jackson, Timothy P. Mill residue availability in the Inland Empire. Forest Products Journal. 35(10): 56-61; 1985.

Keegan, Charles E.; Jackson, Timothy P. Value of wood to competing users: energy versus product uses in the Inland Empire. Forest Products Journal. 36(4): 53-56; 1986.

Keegan, Charles E.; Jackson, Timothy P.; Johnson, Maxine C. Idaho's forest products industry, a descriptive analysis, 1979. Missoula, MT: Bureau of Business and Economic Research, University of Montana; 1982. 98 p.

Keegan, Charles E.; Jackson, Timothy P.; Johnson, Maxine C. Montana's forest products industry, a descriptive analysis, 1981. Missoula, MT: Bureau of Business and Economic Research, University of Montana; 1983. 85 p.

Keegan, Charles E.; Kirkpatrick, Thomas O.; Magnum, Bryan L.; Withycombe, Richard P. Evaluation of the economic feasibility of establishing a concentration yard to utilize the low-value wood resource in the Bitterroot Valley. Missoula, MT: Bureau of Business and Economic Research, University of Montana; 1981. 55 p.

Keegan, Charles E.; White, Randle V. Forest and mill residue in Montana and the potential for major manufacturing plants. Montana Business Quarterly. 17(4): 10-18; 1979 Winter.

Larsen, David; Gee, Loren. 1980 Washington mill survey, wood consumption and mill characteristics. Report No. 7. Olympia, WA: State of Washington, Department of Natural Resources; 1981. 135 p.

Lavoie, Jean-Marc. The transportation of full trees from the stump area to the mill woodyard. Technical Report TR-44. Vancouver, BC: Forest Engineering Institute of Canada; 1980. 35 p.

Levi, Michael P.; O'Grady, Michael J. Decisionmaker's guide to wood fuel for small industrial energy users. SERI/TR-8234-1. Golden, CO: Solar Energy Research Institute; 1980. 127 p.

Lin, Geng-Bor. Wood-fired steam production—a case study. Madison, WI: Forest Products Journal. 33(718): 63-69; 1983.

Montana Department of State Lands. Timber resources of Lincoln, Sanders, Flathead, and Lake Counties. Missoula, MT: Montana Department of State Lands; Intermountain Forest and Range Experiment Station; 1982. 202 p.

Park, Jerrold D. [Letter to Charles E. Keegan.] 1984. Located at: University of Montana, Missoula.

Pennington, H. William. Market expansion forecasts for reconstituted boards. Forest Industries. 111(4): 40; 1984.

Rafferty, Kevin. Retrofit considerations for biomass fuel use at seven selected correction facilities in Washington State. WS-SGTA-84-2. Olympia, WA: Washington State Energy Office; 1984. Not consecutively paged.

Routhier, Jean-Guy. Implications of full-tree harvesting for biomass recovery. ENFOR Project P-54. Sainte-Foy, PQ: Canadian Forestry Service, Department of the Environment; 1982. 132 p.

Schuchart and Associates. Feasibility study of wood-residue-fired cogeneration at Heppner, OR. EPRI AP-1403. 1980. Unpublished report on file at: Electric Power Research Institute, Palo Alto, CA. Not consecutively paged.

U.S. Department of Agriculture, Forest Service. Environmental statement: Northern Region's slash disposal program. 1974. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Northern Region, Missoula, MT.

U.S. Department of Agriculture, Forest Service. Structural flakeboard from forest residues; Proceedings of a symposium; 1978 June 6-8; Kansas City, MO. General Technical Report WO-5. Washington, DC: U.S. Department of Agriculture, Forest Service; 1978. 241 p.

U.S. Department of Agriculture, Forest Service. The Kootenai National Forest draft environmental impact statement. 1982. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Kootenai National Forest, Libby, MT. Not consecutively paged.

U.S. Department of Energy. Bioenergy bulletin. Portland, OR: U.S. Department of Energy, Bonneville Power Administration, Pacific Northwest Biomass Utilization Task Force; 1982. Volume IV, No. 1, p. 2.

U.S. General Accounting Office. The Nation's unused wood offers vast potential energy and product benefits.

Report to the Congress of the United States by the Comptroller General. Gaithersburg, MD: U.S. General Accounting Office, Document Handling and Information Services Facility; 1981. 115 p.

Withycombe, Richard P. The outlook for particleboard manufacture in the Northern Rocky Mountain region. General Technical Report INT-21. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 39 p.

APPENDIX A: AN ANALYSIS OF AVAILABLE VOLUMES AND RECOVERY COSTS OF LOGGING RESIDUE IN NORTHWESTERN MONTANA

Logging Residue Volume Estimates

The forest residue resource most readily available for utilization is material currently being left on the logging site. This material is referred to as logging residue and includes the following components:

1. Large dead or cull green trees and logs, including cull portions of the bole of sawtimber trees bucked-out and left on the logging site, referred to hereafter as large logging residue.
2. Crowns and unmerchantable bole tips of sawtimber trees.
3. Submerchantable stems growing in a mixture with sawtimber material.

Annual available volumes were estimated for a supply area bounded by a 100-mile haul to Libby, MT. The volume and condition of logging residue were estimated by applying residue factors to projected annual timber harvest volume and characteristics. For component 1 above (large logging residue), residue volume factors were developed from a comprehensive inventory of recently logged-over lands. For components 2 and 3, the residue volume factors were developed from tree volume and stand tables. Projections of harvest levels and characteristics were obtained from major timberland owners and managers in the region. See appendix B for a discussion of timber harvest levels in the supply area.

ESTIMATING THE VOLUME OF LARGE LOGGING RESIDUE

The initial emphasis in logging residue analysis was placed on large logging residue, because material from this source is immediately available in the course of sawtimber logging operations. Its recovery would require no change in the conventional logging operation in Montana.

The inventory of recently logged-over areas was initiated concurrent with a statewide field inventory of logging residue being conducted by the Pacific Northwest Forest and Range Experiment Station (Howard and Fiedler 1984). Two crews were added to the crews doing the State-level inventory, and recently logged areas within a 100-mile haul of Libby, MT, were sampled in more detail to enhance the information available for the area from the State-level inventory. The results of the inventory are included in Howard and Fiedler (1984), as are a description of the methodology and field inventory instructions.

The residue inventory designed by Howard and Fiedler accomplished two primary objectives:

1. Appropriate analytical tools were developed to estimate the volume of logging residue for any uniquely designed supply zone in Montana. Volume estimators (ratios) developed in this study relate residue volume to both timber harvest volume and acreage. One ratio estimates the cubic foot volume of residue associated with the harvest of 1,000 bd ft Scribner of sawtimber (cubic feet per thousand board feet). The other ratio provides an estimate of cubic foot volume of residue per acre harvested (cubic feet per acre).
2. Residue was described and classified based on characteristics that affect utilization. Characterization of residue materials includes the following:
   a. Gross and net volume of logging residue by diameter and length, for live and dead or cull material. Gross volume is the volume of a piece of residue material measured only by its external dimensions; it includes rot, cracks, and missing parts. Net volume is the volume of the usable portion of a piece of residue; for this report usability is based on physical chippability of the material.
   b. Number of pieces of residue per acre, by diameter and length.
   c. Volume of residue by percentage sound (chippability), in cubic feet per acre.
   d. Accessibility of residue on cutover areas, by slope and distance to road.
   e. Volume by potential product.

The residue inventory included all material greater than 3 inches in diameter with a length of 1 foot or more. The residue data were analyzed in four strata considered to exhibit significantly different residue generation characteristics:

1. National Forest clearcuts—seed-tree cuts (other than lodgepole pine).
2. National Forest partial cuts (other than lodgepole pine).
3. Private lands (other than lodgepole pine—all cuts).
4. Lodgepole pine stands (all ownerships—all cuts).

Where mixed stands occurred, the stand was classified as lodgepole pine if 95 percent of the stand volume was comprised of lodgepole pine.

CHARACTERISTICS OF INVENTORIED LOGGING RESIDUE

The logging residue inventory data indicate large volumes of wood fiber of widely variant condition, class, and size remaining on logged-over areas in the residue supply zone surrounding Libby, MT. The net volume of wood residue in pieces at least 1 foot in length with small end diameter greater than 3 inches ranged from 69 ft^3/thousand bd ft Scribner harvested on the lodgepole pine sites, to an average of 134 ft^3/thousand bd ft harvested on private ownerships. The National Forest clearcut-seed tree stratum and partial cut stratum contained respectively 111 and 99 ft^3 of residue per thousand bd ft harvested (table 7).

Table 7—Average gross and net volume of logging residue by residue type and stratum in the defined Libby supply area

Stratum	Wood		Wood and bark	
	Gross	Net	Gross	Net
	---- Ft^3/thousand bd ft Scribner ----			
Public				
Clearcut/seed tree cut	148	87	172	111
Partial cut	134	77	156	99
Private	187	98	224	134
Lodgepole pine[1]	93	59	103	69

[1]95 percent of stand volume was lodgepole pine.

The estimated board foot to cubic foot conversion factor for sawtimber (sawlogs and veneer logs) in Montana is 4.8 bd ft/ft^3 (Keegan and others 1983). Based on this factor, 1,000 bd ft Scribner would contain 208 ft^3. The inventory indicated, therefore, that for the four strata an estimated net residue volume equivalent to 33 to 64 percent of the sawtimber volume harvested remains on logging sites in the supply zone, in pieces longer than 1 foot with a diameter greater than 3 inches.

The annual sawtimber harvest in the area is projected to be approximately 440 million bd ft Scribner or about 92 million ft^3. This translates to approximately 45 million ft^3 or 450,000 cunits of logging residue generated annually. This volume is substantially in excess of the 250,000 cunits that would be required to supply a wood-fired power plant 40-50 megawatts in size.

ESTIMATES OF REASONABLY RECOVERABLE RESIDUE VOLUMES

All 450,000 cunits are recoverable given a high enough market price. Not all are recoverable, however, at a price that would be considered reasonable given most potential uses. The volume of usable wood per piece is a major factor in determining the cost of recovering timber of any kind. Usable wood is determined by piece size and condition or soundness. The percentage of gross volume that is sound indicates both net piece size and whether or not that particular piece is sound enough to be effectively harvested in a logging operation.

Two parameters, one for soundness and one for piece size, were used to identify the volume of logging residue recoverable within a reasonable cost range. First, it was assumed that any piece less than 40 percent sound would not be recoverable. After the adjustment for soundness, it was assumed that any piece with a net volume, including bark, of less than 4 ft^3 would not be recoverable. It was further assumed that a piece had to be 8 feet long to be recoverable. The soundness guideline was developed based on a discussion with a number of companies and individuals who have been handling nonsawtimber wood fiber. The piece size guideline was selected based on the logging residue cost model developed by the Bureau of Business and Economic Research (Jackson and others 1984b). The soundness and piece size cutoffs are somewhat arbitrary, but the limits are reasonable and conservative. In fact, some material that would be very expensive to recover is included.

Table 8 indicates the effect of the adjustment for soundness and then for piece size. Column 1 indicates by strata net wood residue and bark volume for all wood fiber material with a small end diameter greater than 3 inches. Column 2 shows the net wood residue and bark volumes for material greater than 40 percent sound. In all strata more than 80 percent of the net wood fiber was in pieces greater than 40 percent sound. Column 3 indicates, however, that only a small portion of the material greater than 40 percent sound is large enough to be removed for a reasonable cost in its present condition.

To illustrate piece size distribution of potentially recoverable material, tables 9 through 12 indicate for each stratum the percentage of material greater than 40 percent sound in various size classes, based on small-end diameter and length. Material over 4 ft^3 is generally in the cells surrounded by the dark line. The tables indicate again that only a relatively small portion of the net residue volume is in the larger piece sizes. The percentages are: National Forest clearcut—seed-tree cuts, 22 percent; National Forest partial cuts, 20 percent; private lands, 9 percent; and lodgepole pine, 6 percent.

Each stratum has less than 25 percent of the net wood residue (greater than 40 percent sound) in pieces 4 ft^3 or larger net volume and greater than 8 feet in length. The public land strata have the highest volume of wood residue in the larger size classes. The volumes, however, are not large, averaging 24 ft^3 of residue per thousand board feet of sawtimber harvested on clearcut—seed-tree cuts, and 20 ft^3 on partial cuts. Private lands had 12 ft^3 of larger residue per thousand board feet of sawtimber harvested. The lodgepole pine stratum had a very low volume of residue in large pieces, with only 4 ft^3/thousand bd ft remaining after logging.

Table 8—Average net volume of wood residue and bark in the defined Libby supply area

Stratum	All residue material	Residue >40% sound	Material >4 ft^3/piece and longer than 8 ft
	---------- Ft^3/thousand bd ft Scribner ----------		
Public			
Clearcut/seed tree cut	111	98	24
Partial cut	99	86	20
Private	134	110	12
Lodgepole pine[1]	69	63	4

[1]95 percent of stand volume comprised of lodgepole pine.

Table 9—Size distribution of logging residue available from National Forest clearcut and seed tree cut units in the defined Libby supply area as a percentage of total net sound residue volume[1]

	Length (ft)				
Small-end diameter	**1 - 7.9**	**8 - 15.9**	**16 - 23.9**	**24+**	**Total**
Inches	*Percent*				
3 - 3.9	5	9	8	13	35
4 - 5.9	8	7	6	4	25
6 - 7.9	3	7	1	5	16
8+	8	3	5	8	24
Total	24	26	20	30	100

[1]Units do not include lodgepole pine sites. "Net sound volume" includes all material greater than 3 inches small-end diameter, 1 foot in length, and more than 40 percent sound.

Table 10—Size distribution of logging residue available from National Forest partial cut units in the defined Libby supply area as a percentage of total net sound residue volume[1]

	Length (ft)				
Small-end diameter	**1 - 7.9**	**8 - 15.9**	**16 - 23.9**	**24+**	**Total**
Inches	*Percent*				
3 - 3.9	5	9	7	14	35
4 - 5.9	12	8	4	8	32
6 - 7.9	3	5	2	5	15
8+	5	4	2	7	18
Total	25	26	15	34	100

[1]Units do not include lodgepole pine sites. "Net sound volume" includes all material greater than 3 inches small-end diameter, 1 foot in length, and more than 40 percent sound.

Table 11—Size distribution of logging residue available from private lands in the defined Libby supply area as a percentage of total net sound residue volume[1]

	Length (ft)				
Small-end diameter	**1 - 7.9**	**8 - 15.9**	**16 - 23.9**	**24+**	**Total**
Inches	*Percent*				
3 - 3.9	8	9	9	10	36
4 - 5.9	6	8	3	3	20
6 - 7.9	6	7	1	2	16
8+	16	6	4	2	28
Total	36	30	17	17	100

[1]Units do not include lodgepole pine sites. "Net sound volume" includes all material greater than 3 inches small-end diameter, 1 foot in length, and more than 40 percent sound.

Table 12—Size distribution of logging residue available from lodgepole pine sites in the defined Libby supply area as a percentage of total net sound residue volume[1]

	Length (ft)				
Small-end diameter	**1 - 7.9**	**8 - 15.9**	**16 - 23.9**	**24+**	**Total**
Inches	*Percent*				
3 - 3.9	7	13	9	18	47
4 - 5.9	9	7	9	9	34
6 - 7.9	4	2	1	2	9
8+	4	3	2	1	10
Total	24	25	21	30	100

[1]95 percent of stand volume comprised of lodgepole pine. "Net sound volume" includes all material greater than 3 inches small-end diameter, 1 foot in length, and more than 40 percent sound.

Table 13—Volume of logging residue 4 ft^3 and larger in size available annually within the designated Libby supply area, by piece size and stratum

Size range	Average piece size	Stratum: National Forest clearcut/seed-tree cuts	National Forest partial cuts	Lodgepole pine	Private	Total volume
Ft³/piece	*Ft³*	*Cunits*				
4	4	3,468	1,967	—	—	5,435
5-7	6	20,712	9,265	2,418	5,974	38,369
8-10	9	6,936	635	—	1,226	8,797
11-15	13	3,468	—	—	2,451	5,919
Above 15	25	6,936	1,333	822	4,749	13,840
Total		41,520	13,200	3,240	14,400	72,360

The volume of residue economically recoverable, using the 4-ft^3 and 8-foot length minimum criteria, is obviously only a fraction of total residue. Given the annual harvest of 440 million bd ft of timber in the supply area, an estimated 72,000 cunits of sound material meeting those specifications would be available annually (table 13). Of the 72,000 cunits available, 57 percent is available from National Forest clearcut and seed-tree cuts, 20 percent from private lands, 18 percent from National Forest partial cuts, and 4 percent from lodgepole pine stands.

The logging residue inventory was also used to estimate the volume of cull portions of sawtimber trees bucked-out and left on the logging site, but shorter than 8 feet (and therefore not included in the estimate of economically recoverable material, above). This material could be economically recovered through harvesting the entire merchantable bole and recovering cull portions at some intermediate processing point. The volume of green residue material less than 8 feet in length and greater than 4 inches in small-end diameter was adopted as a direct estimate of bucked-out short sections. The estimated volume of such material amounts to 38,000 cunits available annually.

ESTIMATING THE VOLUME OF CROWN AND UNMERCHANTABLE BOLE TIP RESIDUE

Crown and unmerchantable bole tip residue potentially recoverable during sawlog harvesting operations is a function of the structure and character of the stands being logged. To estimate this residue volume, stand information was developed for the average sawtimber stand expected to be harvested in the supply area during the next decade. Sixty-eight random samples of individual sawtimber stands were selected from Forest Service inventory data within the supply area surrounding Libby, MT. Each sample provided a measure of the number of stems per acre and volume per acre of boles of standing trees by diameter class. These, in turn, were summarized to develop the "average" sawtimber stand structure for the area. The diameter distribution and bole volume per acre for this average stand are shown in table 14.

Other investigators, including Brown and others (1977) and Faurot (1977), have developed volume factors estimating volumes of bole, bole tip, and crown material in individual trees. Average bole, tip, and crown volumes for individual trees are shown in table 15, for 2-inch diameter classes from 4 to 20 inches. Applying crown and bole tip factors to trees in the 8-inch and larger diameter classes in the average sawtimber stand (table 14) resulted in an estimated residue volume per acre of 1,110 ft^3 recoverable from sawtimber trees. Averages of two tree diameter classes (table 15) were used as necessary to correspond to defined diameter classes in the representative sawtimber stand.

Table 14—Average number and volume of standing trees per acre in sawtimber stands, by diameter class, in the defined Libby supply area

Standing trees diameter class	Average diameter	Volume per acre	Stems per acre
Inches		*Ft³*	*Stems*
3 - 4.9	4	134	112
5 - 6.9	6	312	80
7 - 8.9	8	532	66
9 - 13.9	11	1,430	85
14 +	17	1,922	35

Source: Based on unpublished data from the USDA Forest Service Northern Region Edit Stand Listing and Stand Exam Data, Regional Office, Missoula, MT.

Table 15—Estimates of average merchantable bole, top, and crown volumes of individual western conifer trees

Tree d.b.h.	Bole and bark volume to a 3-inch top	Crown and bole volume above a 3-inch top	Total volume
Inches	*Ft³*		
4	1.0	1.2	2.2
6	3.2	2.0	5.2
8	8.4	3.1	11.5
10	16.1	4.6	20.7
12	27.2	6.5	33.7
14	39.8	8.7	48.5
16	55.6	11.1	66.7
18	74.9	14.1	89.0
20	98.0	17.5	115.5

Sources: Brown and others 1977; Faurot 1977. Cubic foot volumes represent four species: Douglas-fir, ponderosa pine, western larch, and lodgepole pine.

Dividing estimated residue volume per acre by the average recoverable sawtimber volume per acre of 15,000 bd ft then establishes an average potential crown and bole tip residue recovery of 74 ft^3/thousand bd ft of sawtimber harvested. It was assumed that the same ratio would apply to the other land ownerships in the supply area. Applying this recovery factor to the estimated 440 million bd ft of sawtimber harvested within the supply zone indicates an estimated 32.5 million ft^3 or 325,000 cunits of additional wood fiber potentially available annually in the form of crowns and unmerchantable bole tips of sawtimber trees.

ESTIMATING THE VOLUME OF SMALL SUBMERCHANTABLE STEM RESIDUE

Based on the sample timber inventory data for the Libby supply zone, the average sawtimber stand includes 5.3 trees in the 5- to 7-inch diameter category per thousand board feet of harvestable sawtimber in the stand (table 14). Each tree contains an average volume of 5.2 ft^3, including crown. Given, again, a harvest of 440 million bd ft, there would be an estimated 12.1 million ft^3 or 121,000 cunits of material in submerchantable stems potentially recoverable annually in conjunction with sawtimber harvesting operations. Trees under 4 inches d.b.h. were assumed to be too small to recover economically.

TOTAL VOLUME OF LOGGING RESIDUE POTENTIALLY AVAILABLE

In summary, an estimated 556,000 cunits of additional wood fiber are potentially available from logging residue. This volume is distributed in the following manner:

	Thousand cunits available in the supply area		
Large logging residue (>4 ft^3)	72		
Cull sections of sawtimber trees	38		
Subtotal:	110		
Crown components of sawtimber trees		325	
Submerchantable trees (5-7 inches d.b.h.) on sawtimber sale areas		121	
Subtotal:		446	
Total:			556

Methods of Logging Residue Recovery

The amount of residue that can be recovered and the costs of recovery are very dependent on the methods employed and/or the type of equipment used. This section presents a brief description of the three recovery methods that were evaluated for high-volume recovery of logging residue in the Libby area.

RELOGGING RECOVERY METHODS

On sites that have already been logged and the residue left, there is no alternative for residue collection other than relogging. The recoverable residue material consists of large dead or cull green trees and logs, and cull portions of the boles of sawtimber trees bucked-out during the course of sawtimber harvesting. For relogging, conventional logging equipment would be moved back to the site just to collect residue. After collection the material could be transported to the mill site for processing.

LOG-LENGTH RECOVERY METHODS

A log-length residue recovery system would also involve the recovery of large dead or cull green trees and logs, and cull portions of the bole of sawtimber trees normally bucked-out and left on site. This would occur in conjunction with the conventional sawtimber harvesting operation and would involve virtually no change in most harvesting operations except for a change in utilization standards. Almost all of the timber currently harvested is in log-length form.

This system would require loading and hauling the large dead or cull green material directly to the mill site for processing. The merchantable boles of sawtimber trees would be loaded intact and the cull portions bucked-out at the mill site.

WHOLE-TREE RECOVERY METHODS

The economic recovery of the limbs and unmerchantable bole tips of sawtimber trees and small submerchantable stems requires the implementation of whole-tree logging systems. There are typically two approaches to recovery: in-woods processing or processing at the mill site. Both approaches require skidding the whole tree (branches and top intact) to the landing. The in-woods processing system involves processing the limbs, tops, and submerchantable stems on the landing. Mill site processing requires loading the whole trees onto logging trucks and processing the material at the mill. The relative advantages and disadvantages of each approach are discussed in detail in the next section.

Logging Residue Availability and Cost Estimates

The projection of recovery costs for logging residue requires information on size and condition of the material to be harvested, and information on a number of additional variables as well, including:

- Method of removal (either cable yarding or ground skidding).
- Average skidding or yarding distance for each site.
- Haul distance to Libby, MT.

Information descriptive of these variables was developed for the projected harvest by obtaining actual site-by-site harvest data, primarily for the years 1981 and 1982, from various land management agencies and major forest products firms in the area. These historical data were adjusted to reflect any major changes in harvest that land managers felt would occur in the 1986-95 period. Site-specific timber harvest data were not available for all ownerships, especially the nonindustrial private lands. Volume and species composition of the annual harvest were, however, generally available for these ownerships, and other components of the harvest operation for these lands were estimated from data from the known sources.

As discussed in the previous section, residue volume factors were used to estimate, from green merchantable volume harvested, the residue generated and its condition and piece size for each site. A cost model developed by the Bureau of Business and Economic Research (Jackson and others 1984b) was used in conjunction with defined timber harvest characteristics to estimate the cost of delivering the residue to a designated locality. The site-by-site data were then summarized for the supply area and the volumes sorted by cost and type of residue material.

COST AND AVAILABILITY FROM RELOGGING

There are two factors that significantly affect the estimated costs of potential relogging in the supply zone. First, the material large enough to consider removing is actually relatively small in average size; second, the volume of wood fiber per acre in recoverable pieces is low. Table 16 indicates the estimated piece size distribution of large sound logging residue per thousand board feet of sawtimber harvested for the four strata. In all but the private stratum, 75 percent of the material is in pieces under 10 ft^3 in size. Half the large sound material is over 10 ft^3 in size in the private stratum. Volume per acre is also an important factor when developing costs of recovering logging residue through a relogging operation. Table 17 illustrates the volume and piece count per acre of material greater than 4 ft^3 in size.

National Forest clearcuts and seed-tree cuts contain the largest estimated recoverable volumes per acre, followed by National Forest partial cuts. The estimated volumes of recoverable material are 431 and 208 ft^3/acre, respectively. These volumes are still low, being roughly equivalent to sawtimber volumes of less than 2,000 and 1,000 bd ft Scribner/acre, respectively. The inventory indicates very low volumes of larger material left on lodgepole pine sites and private lands—less than 100 ft^3/acre or under 500 bd ft Scribner/acre equivalent in each case. Recovering residue by relogging from lodgepole pine and private sites was consequently not considered feasible because of such low volumes.

Based on the recoverable volumes just described, an estimated 55,000 cunits of logging residue on National Forest clearcut and partial-cut sites would be available annually in the supply area. Applying an estimated breakage factor of 20 percent (Keegan 1981) would reduce actual recoverable volume to 44,000 cunits. The estimated cost of recovering this material is $90 per cunit, **excluding** equipment setup and transportation costs.

The low volumes of recoverable material per acre have further implications for both volume recovery and cost.

Table 16—Estimated volume of logging residue 4 ft^3 and larger per thousand bd ft, Scribner, of sawtimber harvest, by piece size and stratum, in the defined Libby supply area

Piece size range	Average piece size	Stratum: National Forest clearcut/seed-tree cut	National Forest partial cut	Private	Lodgepole pine[1]
Ft³					
4	4	2	3	—	—
5 - 7	6	12	14	5	3
8 - 10	9	4	1	1	—
11 - 15	13	2	—	2	—
Above 15	25	4	2	4	1
Total		24	20	12	4

[1]95 percent of the stand volume comprised of lodgepole pine.

Table 17—Volume and piece count of logging residue 4 ft^3 and larger per acre of sawtimber harvest, by piece size and stratum, in the defined Libby supply area

Piece size range	Average piece size	Stratum: National Forest clearcut/seed tree cut	National Forest partial cut	Lodgepole pine[1]	Private	National Forest clearcut/seed tree cut	National Forest partial cut	Lodgepole pine	Private
Ft³		*Ft³/acre*				*Pieces/acre*			
4	4	36	31	—	—	9.0	7.7	—	—
5 - 7	6	215	146	50	39	35.8	24.3	8.3	6.5
8 - 10	9	72	10	—	8	8.0	1.1	—	0.9
11 - 15	13	36	—	—	16	2.8	—	—	1.2
Above 15	25	72	21	17	31	2.9	0.8	0.7	1.2
Total		431	208	67	94	58.5	33.9	9.0	9.8

[1]95 percent of the stand volume comprised of lodgepole pine.

Because harvesting equipment capacity is likely to be significantly underutilized, recovery could be extended to include smaller material in the 3-ft^3 (and perhaps even 2-ft^3) size classes without appreciably changing the cost per cunit. The volume of recovered residue could be thereby increased, perhaps substantially (see tables 9 and 10). On the cost side, however, low volumes per acre are likely to mean frequent equipment moves, with associated transportation and setup costs. The $90 cost per cunit must be considered a conservative cost.

In summary, relogging recently logged sites in the supply area does not appear to offer an economically viable potential for large volume residue users. A cost of $90 per cunit is higher than any user in the Libby area would currently be willing to pay for residue material.

Relogging Opportunities for Small Volume Users—Relogging will be expensive for any user operating on logged-over sites with conventional sawtimber logging equipment. But wood fiber from these sites may be available at a more reasonable cost to low-volume, low-fixed-cost operations—for example, a chainsaw and pickup truck. These could include home fuelwood gatherers or cedar products harvesters. Based on the inventory data, however, volumes of sound, relatively large pieces of wood fiber on recently logged sites in the area are very limited and even opportunities for low-volume, low-fixed-cost operations are few.

COST AND AVAILABILITY FROM LOG-LENGTH RECOVERY METHODS

With little change in the typical log-length sawtimber operation, additional large cull timber and cull portions of sawtimber boles could be recovered at the time sawtimber is being logged. Residue inventory data were used earlier to estimate the volumes of these components of logging residue. It was assumed that inventoried material with a net volume greater than 4 ft^3, more than 40 percent sound, and at least 8 feet in length would represent the additional large material available when the site was originally logged. The volume of green material less than 8 feet long and greater than 4 inches in small-end diameter remaining on sites was used to estimate the volume of cull material bucked-out of sawtimber logs.

Volumes Available and Cost—A log-length recovery operation at the time of sawtimber harvesting offers the potential to recover considerably larger volumes of additional wood fiber than does relogging. Because residue recovery would be accomplished in conjunction with the sawtimber operation, a low volume of recoverable residue per acre would not adversely influence recovery, and residue could be recovered from all sites, including those on private lands and lodgepole pine sites where relogging was determined to be infeasible. Additional material could also be recovered during the initial logging operation by leaving the cull portions of sawtimber boles attached during logging. Table 18 indicates the estimates of residue volumes available through log-length residue recovery for each of the four strata.

The recovery of residue wood fiber in a log-length operation at the time of original entry for sawtimber would offer a total of 110,000 cunits of nonsawtimber wood fiber per year in the supply zone. After adjustment for breakage, this figure would be reduced to an estimated 96,000 cunits. This represents an increase of 52,000 cunits over the estimated volume available through relogging. Of the 96,000 cunits of recoverable residue, 58,000 cunits are dead or large cull material, and an estimated 38,000 cunits are from bucked-out portions of sawtimber trees. The estimated average cost to harvest, transport, and chip this material was $74 per cunit. The $74 per cunit average cost includes a relatively wide range of costs for various components. A user could recover selected components of this material for much less than $74 per cunit. For example, an estimated 40 percent of the material (38,000 cunits) was originally part of the bole of a sawtimber tree. Previous studies have indicated that unmerchantable portions of sawtimber trees can be moved to the landing without increasing costs significantly (Hedin 1980; Lavoie 1980; Routhier 1982). In estimating specific recovery costs for the 38,000 cunits recoverable as part of a larger sawlog piece, it was assumed that the cull portions could be moved to the landing for no cost. The costs incurred were loading, hauling, and chipping. The estimated cost of recovering cull portions of sawtimber logs in this manner is $30 per cunit. Costs vary for the remaining log-length residue material. Material on tractor ground, for example,

Table 18—Wood fiber residue available from application of log-length logging systems in the defined Libby supply area

Source	National Forest clearcut/ seed tree cuts	National Forest partial cuts	Private lands	Lodgepole pine sites[1]
	Stratum			
	- - - - - - - - - - - - - - *Thousand cunits* - - - - - - - - - - - - - -			
Cull portions of sawtimber boles	11	6	16	5
Large cull pieces (4 ft^3 and larger) left in logging	22	20	12	4
Total	33	26	28	9

[1]95 percent of stand volume comprised of lodgepole pine.

has an estimated recovery cost of $65 per cunit, while on cable ground the estimated cost is over $80 per cunit. Table 19 describes the estimated costs of recovering various components of log-length residue material.

Ideally, a using firm would have access to all harvest sites in the supply area, and would select and harvest desired material in perfect increments from cheapest to most expensive. In actual practice, the firm would likely set broad guidelines for harvesting residue that would define piece size limits, haul distances, and other criteria that would in effect result in recovering the less expensive material first.

COST AND AVAILABILITY FROM WHOLE-TREE RECOVERY METHODS

Costs of recovery of unmerchantable bole tip and crown wood from sawtimber trees are potentially low because felling, limbing, bucking, and skidding costs may be unaffected or actually decrease when a whole-tree operation is substituted for a conventional log-length operation (Hedin 1980; Lavoie 1980; Routhier 1982). That is, a whole tree can generally be moved from the stump to the landing on the logging site for no more, and perhaps less, than it would cost to move only the logs in that tree. Costs incurred in processing the material at the landing (or mill) are consequently the only costs of recovery of this material that otherwise would remain in the woods.

There is a relatively high level of uncertainty associated with estimating the costs of recovery of bole tip and crown wood. There is very limited quantitative information available on recovery of the material and available data are generally from regions other than the Inland West. In addition, the existing data reflect a high level of variation associated with species and season of year.

The recovery of bole tip and crown wood involves the acquisition of relatively expensive equipment and incurs considerable fixed costs. The operation generally requires some sort of whole-tree processor in addition to a chipper. Both a chipper and a whole-tree processor are expensive and must be run at relatively high rates of production to achieve low cost. If sufficient volumes of top and crown wood are available, delimbing, topping, and chipping costs should be low. In fact, for small-diameter sawtimber trees, limbing costs using a whole-tree processor at a high level of capacity utilization should be considerably lower than limbing costs by hand, resulting in an actual cost savings. On the other hand, if the volume of bole tip and crown wood recovered is low, the level of utilization of this equipment will also be low and the cost of operating the machines per cunit will be high. Low recovery volumes can greatly increase the cost of recovering top and crown wood. Using available information descriptive of fixed costs of whole-tree processing systems and the potential high degree of variation in volume recovery, a range of costs for recovering bole tip and crown wood have been estimated.

In-woods Versus Mill Site Processing—Two general approaches were analyzed to move the bole tips and crowns from the landing to the mill site. One involves processing in the woods and hauling sawlogs and chipped tops and limbs separately. The second is to haul whole trees to the mill and limb, top, and chip at the mill. The relevant costs in recovering this material in both cases are haul costs and chipping costs. If a whole-tree hauling approach is used, loading costs must also be considered.

When in-woods processing is employed (and sometimes when mill-yard processing is employed), it is often feasible and desirable to recover subsawtimber size trees as well. The assumption is that when whole-tree processing is done in the woods, submerchantable trees can help achieve an adequate level of processing equipment utilization. When chipping is done at the mill-yard, the assumption is that recovery of small trees is optional. When submerchantable whole trees are harvested, relevant costs must include felling and skidding costs in addition to chipping and haul costs. No limbing costs are incurred because submerchantable trees are chipped whole.

Residue Availability and Cost: In-woods Processing of Whole Trees—In-woods processing of whole trees is not feasible on many sites. The following assumptions were made to help identify sites on which in-woods chipping could occur and to provide a basis for estimating the proportion of available residue that could be recovered:

- Adequate landing space will be available only on areas with an average slope of less than 20 percent.
- Breakage of crowns and unmerchantable bole tips during skidding of whole trees will reduce the available bole tip and crown volume by 40 percent.
- Submerchantable stems 4 inches d.b.h. and larger will also be recovered. Loss due to breakage when re-

Table 19—Volume and cost of logging residue potentially available annually from application of log-length operations in the defined Libby supply area—1986-95

Source	Volume	Estimated cost/cunit
	Thousand cunits	*1984 $*
Large cull material on tractor ground	41	65
Cull portions contained in sawtimber boles		
Tractor ground[1]	30	30
Cable ground[1]	8	30
Large cull material on cable ground	17	Over 80
Total	96	

[1]Costs are the same based on the assumption that if the cull portion is not removed from the sawtimber bole, no additional skidding or yarding costs would be incurred. Costs are those of processing the bole to recover material.

covering small stems will be assumed to be 25 percent of the whole-tree volume.

- The timber harvested must be relatively homogeneous and under 20 inches in diameter.

Based on inventory data and current and projected harvest data, approximately 36 percent of the harvest will come from slopes under 20 percent with relatively homogeneous stands under 20 inches in diameter (USDA FS 1984). Of the projected 440 million bd ft annual harvest in the supply area, approximately 160 million bd ft would therefore be readily accessible to whole-tree harvest systems involving in-woods processing of the trees. This harvest volume would yield an estimated 118,000 cunits of forest residue annually in the supply zone from whole-tree harvesting operations utilizing in-woods chipping. Of this volume an estimated 71,000 cunits would be crown components of sawtimber trees, 33,000 cunits would be boles and crowns of submerchantable trees, and 14,000 cunits would be cull portions of stems. The estimate of volumes of cull portions of sawtimber trees available annually from all logging sites in the area is 38,000 cunits as discussed earlier. It was assumed that 36 percent of this material, or 14,000 cunits, would also be available through an in-woods chipping system.

When developing cost estimates for material chipped on the logging site, it was assumed that mechanized harvesting equipment would be used. System costs would be sensitive to volume being processed, with costs per cunit increasing significantly as volume declines. Haul costs of chipped material would be much less affected by variation in volume recovery. It was assumed that loading and hauling chip vans could be accomplished with only normal delay time, but that chipping costs could easily be tripled if volumes processed were reduced. The lower bound for the cost range was therefore established at normal industry haul costs and chipping costs as developed in prior investigations of residue recovery cost (Jackson and others 1984b). The upper bound was established at normal haul cost and three times the normal chipping rate, again based on the same cost model.

Based on these assumptions and an average haul distance of 50 miles, the cost range for recovering crown and bole tip wood fiber was \$25 to \$45 per cunit. Estimated average cost of recovering material in submerchantable trees was considerably higher, \$65 per cunit. The estimated cost of the 14,000 cunits of material recovered from cull portions of boles of sawtimber trees was \$30 per cunit. In summary, the estimated cost of delivering chipped wood fiber from an in-woods processing system would range from \$25 to \$65 per cunit. Again, the volume available in the entire supply area is an estimated 118,000 cunits.

Residue Cost and Availability: Whole-Tree Hauling to the Mill Site—Whole-tree hauling appears to offer a larger volume of forest residue recoverable at a reasonable cost than any method discussed thus far. Because landing size limitations should not be as serious a constraint as with in-woods chipping, whole-tree hauling could make available the crown components of sawtimber trees on virtually all harvesting units. Of course, this system is not without limitations and has not been implemented on a broad scale in the Inland Empire.

The assumptions adopted for estimating the application of whole-tree hauling recovery system are as follows:

- Whole-tree hauling can be implemented on all sites, but is limited to trees with diameters less than 14 inches.
- An examination of stand structure indicated that such an assumption (that whole-tree systems could be employed effectively only in stands with the majority of the sawtimber volume in stems under 14 inches d.b.h.) would not significantly affect the estimate of top and crown wood available in the supply zone.
- Loss due to breakage of the crown components of sawtimber whole trees logged and hauled amounts to 40 percent of the total volume.
- Breakage of small stems (5 to 7 inches d.b.h.) amounts to 25 percent of the whole-tree volume.
- Recovery of small stems will be limited to harvest systems using sites suitable for grapple skidding in conjunction with mechanized felling and bunching. In this case it was assumed that mechanized harvesters necessary to harvest small stems would operate on all sites under 20 percent slope.

Implementing a whole-tree hauling system on all suitable logging sites in the area would make available an estimated 119,000 cunits of crown and bole tips of sawtimber trees, 33,000 cunits of the boles and crowns of submerchantable trees, and 38,000 cunits from the cull portions of the boles of sawtimber trees.

If sawtimber trees are hauled whole to a mill site, relevant costs of recovering tops, limbs, and cull bole portions should include loading and haul costs as well as in-plant chipping costs. An additional haul cost would, of course, also be incurred when the top and crown wood is to be utilized at a site other than the mill processing the sawtimber. Utilization of chipping equipment (and whole-tree processors) should be greatly increased at the mill site. Normal chipping costs should therefore provide a good estimate of chipping costs (Jackson and others 1984b). Increases in loading costs over those considered normal could be relatively large, however. Information on potential increased loading and unloading costs is limited to a single study which indicated a 30 percent increase in loading and unloading time when whole trees were loaded rather than logs (Lavoie 1980). A study by Routhier (1982) also indicated increased costs of loading and unloading whole trees, but did not provide detailed time and cost estimates. The total load weight per truck in both studies remained the same. The 30 percent increase resulted in the recovery of only 17 percent more wood fiber per tree in the form of top and crown wood, making it nearly three times more expensive per unit volume to load than the logs. The study dealt with small diameter balsam fir and black spruce and may not accurately reflect the situation in the Northern Rocky Mountains. It does indicate, however, that loading costs for tops and limbs attached to whole trees can be considerably higher per unit of volume than for logs. A range was established for loading costs by (1) determining the average piece size based on the volumes of the merchantable bole; (2) using the corresponding loading costs reported by Jackson and others (1984b) as a lower bound; and (3) using a cost of three times that as an upper bound.

Using the described cost factors, the chipped tops and crowns of sawtimber trees recovered by hauling whole trees to the mill site are estimated to have a recovery cost of between $25 and $55 per cunit, given a 50-mile haul. Estimated costs are not a great deal different than those associated with the in-woods method, given that an additional haul cost may be incurred if the tops and limbs chipped at the mill site were to be processed at another site. The risk of greatly increased cost due to low processing equipment utilization, however, should be considerably reduced. The estimated cost of recovering cull portions of the bole of sawtimber trees was $30 per cunit, as discussed in the previous section.

Small stems that might be taken in association with recovering sawtimber tops and limbs would have an estimated cost of $65 per cunit, chipped at the mill site. Because equipment utilization will be at relatively high levels, however, it was assumed that it would be neither desirable nor necessary to take small stems. They would consequently be treated as a separate source of wood fiber rather than part of the recovery potential for a system in which whole trees are hauled to the mill site for processing.

Whole-Tree System: Low-Volume Recovery Potential—Unlike relogging opportunities or log-length residue recovery, whole-tree harvest systems do not offer opportunities to recover small volumes at relatively low cost. Processing whole trees requires expensive equipment, giving these operations a high fixed cost. If sufficient volumes of material are not available to operate the equipment at a relatively high level of production, costs of top and crown wood become very high.

APPENDIX B: PROJECTED TIMBER HARVEST IN THE LIBBY, MT, SUPPLY ZONE, 1986-95

The supply zone for forest residue was designated as a 100-mile haul to Libby, MT. This included not only Lincoln County but also portions of Flathead and Sanders Counties in Montana and Bonner and Boundary Counties in Idaho. The 100-mile haul was established based on the following rationale:

- It generally represents the outer haul distance limit for sawtimber to sawmills and plywood plants in the area.
- A substantial portion of the forest residue resource farther than a 100-mile haul from Libby is closer to other existing potential major users of forest residue.
- Some of the uses of forest residue are relatively low value, making it uneconomical to haul longer distances.

Within the described supply area, principal timber sources include Forest Service lands, State lands, industrial lands owned by large corporations, and private nonindustrial lands. The major suppliers of timber and acreages of timberland are:

- The seven Ranger Districts of the Kootenai National Forest encompassing 1.6 million acres of commercial timberland.
- The Tally Lake Ranger District and portions of the Swan Lake Ranger District, Flathead National Forest, encompassing 280,000 acres.
- The Bonners Ferry Ranger District of the Panhandle National Forests encompassing 420,000 acres.
- Industrial forest land owned by Champion International Corporation and Plum Creek Timber Company encompassing 500,000 acres, mostly in Lincoln and Flathead Counties.
- Nonindustrial private timberlands encompassing over 200,000 acres.
- Other public timberlands, primarily lands managed by the States of Idaho and Montana, encompassing over 80,000 acres.

The harvest from all ownerships within the supply zone is projected to be 440 million bd ft annually from 1986 to 1995. Just under 70 percent of the harvest will be on National Forest timberlands, nearly 20 percent on forest industry lands, and the remaining 10 percent from nonindustrial private lands and other public lands (table 20).

Table 20—Projected annual sawtimber harvest in the defined Libby supply area—1986-95

Ownership source	Volume
	Million bd ft, Scribner
National Forest	
Kootenai	
Cabinet Ranger District	28
Fisher River Ranger District	50
Fortine Ranger District	30
Libby Ranger District	25
Rexford Ranger District	32
Troy Ranger District	20
Yaak Ranger District	50
Flathead	
Swan Lake Ranger District	4
Tally Lake Ranger District	30
Idaho Panhandle	
Bonners Ferry Ranger District	36
Industrial private	85
Nonindustrial private and State	50
Total all ownerships	440

Data compiled from: USDA Forest Service, Kootenai National Forest, Flathead National Forest, and Idaho Panhandle National Forests; St. Regis Paper Co.; Champion International Corp.; and Plum Creek Timber Co.

National Forest Timberlands

The harvest on the Kootenai National Forest from 1986 to 1995 is projected to be 235 million bd ft annually, representing 53 percent of the timber harvest within the designated supply zone. Projections are that the portions of the Flathead National Forest within the supply zone will have an annual harvest of 34 million bd ft, or 8 percent of the total, comprised of about 30 million bd ft from the Tally Lake District and 4 million bd ft from the Swan Lake District. The Bonners Ferry Ranger District, the only Idaho Panhandle Forests unit within the supply zone, has a projected annual timber harvest of 36 million bd ft for the 1986-95 period.

Industrial, Nonindustrial Private, and Other Public Timberlands

Harvest on industrial private lands between 1986 and 1995 is estimated to be 85 million bd ft annually, or about 20 percent of the volume within the supply zone. Resource data are not as readily available for nonindustrial private and other public ownership groups. Mill surveys conducted in 1976, 1979, and 1981 in Montana and Idaho were used in the development of estimates of timber harvest levels from these lands within the supply zone (Bureau of Business and Economic Research 1977, 1981, 1982). The assumption in this analysis is that the harvest levels and characteristics exhibited since 1976 on these lands will continue until 1995. The estimated harvest on nonindustrial lands in the supply area is 35 million bd ft of timber annually for 1986 to 1995. About 20 million bd ft of this volume will originate in Boundary County, ID, and the remaining 15 million bd ft will originate within Lincoln and Flathead Counties in Montana. Other public timberlands are anticipated to provide 15 million bd ft annually within the supply zone. Approximately 8 million bd ft will originate on timberlands in Lincoln and Flathead Counties in Montana, and 7 million bd ft will come from Boundary County, ID.

U.S. GOVERNMENT PRINTING OFFICE:1987-773-039 / 61029

Keegan, Charles E., III; Jackson, Timothy P.; Withycombe, Richard P.; Barger, Roland L.; Chase, Alfred L. 1987. Utilizing wood residue for energy generation in northwestern Montana: a feasibility assessment. Gen. Tech. Rep. INT-234. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 39 p.

Wood residue in northwestern Montana is a potential source of fuel for power generation. The most promising sources of residue are fine mill residue and bark, with quantities dependent upon lumber production, and top, limb, and cull material available through whole tree sawtimber harvesting methods. Utilization of residue for energy is constrained primarily by the cost of recovery of residue material and the relatively low value of the energy produced. A feasibility analysis of both cogeneration and stand-alone electrical power generating facilities indicates that neither would be feasible except under the lowest possible facility and wood fuel costs. Wood residue substitution for natural gas or fuel oil in process steam boilers is economically more attractive, and could support wood fuel costs of $50 or more per cunit.

KEYWORDS: forest residue, wood utilization, wood energy, residue utilization, biomass energy

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

General Technical
Report INT-235

An Annotated Bibliography of the Hydrology and Fishery Studies of the South Fork Salmon River

THE COMPILERS

KATHLEEN A. SEYEDBAGHERI is a hydrologist at the Intermountain Research Station's Forestry Sciences Laboratory in Boise, ID. She attended Boise State University, the University of Notre Dame, and Utah State University, and holds bachelor degrees in anthropology, mathematics, and watershed science. She served as a forestry aide, forestry technician, and hydrologic technician at the Boise laboratory between 1974 and 1980, and has been in her present position since 1980.

MICHAEL L. McHENRY is a biological technician (fisheries) at the Intermountain Research Station's Forestry Sciences Laboratory in Boise, ID. He earned a B.S. degree in fisheries from Humboldt State University in 1982 and an M.S. degree in fisheries science from New Mexico State University in 1986. He has been employed at the Boise laboratory since 1985.

WILLIAM S. PLATTS is a research fishery biologist at the Intermountain Research Station's Forestry Sciences Laboratory in Boise, ID. He received a B.S. degree in conservation-education in 1955 from Idaho State University, an M.S. degree in fisheries in 1957, and a Ph.D. degree in fisheries in 1972 from Utah State University. From 1957 through 1966, he worked as a regional fishery biologist and supervisor in enforcement with the Idaho Fish and Game Department. From 1966 through 1976, he was the Idaho Zone fishery biologist for the USDA Forest Service, Intermountain Region, and consultant to the Surface Environment and Mining (SEAM) program. He has been in his present position since 1976.

CONTENTS

September 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

An Annotated Bibliography of the Hydrology and Fishery Studies of the South Fork Salmon River

Compilers:
Kathleen A. Seyedbagheri
Michael L. McHenry
William S. Platts

INTRODUCTION

This publication provides resource managers with an easily accessible, unified reference source concerning hydrology and fishery studies of the South Fork of the Salmon River drainage in central Idaho. Access to the wealth of knowledge gained on the South Fork, one of the most intensely studied forested river basins in the United States, may serve to promote better multiple-use management in the future.

The South Fork of the Salmon River drainage, part of the Columbia River basin, comprises an area of 826,700 acres (fig. 1). The watershed is almost entirely within the Idaho batholith. Approximately a third of the land in the drainage lies within the Boise National Forest and about two-thirds is within the Payette National Forest (USDA FS 1985).

Elevations range from 2,700 to 9,280 feet, with about half of the drainage in the 5,000- to 7,500-foot class. The area is characterized by steep slopes with overstory vegetation dominated by ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) at the lower elevations, and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) at the higher elevations (USDA FS 1985).

Summers are typically hot and dry, with warm-season precipitation occurring primarily during high-intensity thunderstorms. Winters are characterized by heavy snows and cold temperatures. Long-duration, low-intensity storms are common in fall, winter, and spring. Most of the annual precipitation falls as snow.

The granitic bedrock of the batholith produces shallow, coarse-textured soils that exhibit high erosion rates, especially when exposed or disturbed. Natural sediment production (assuming undisturbed watershed conditions) within the South Fork watershed is estimated at 65,000 tons per year (USDA FS 1985).

The South Fork basin has a wealth of resources involving minerals, recreation, timber, water, forage, wildlife, and fish. Active mining claims currently being administered total 104. The largest cyanide heap leach gold mine in the State of Idaho is operating in the Stibnite area, in the headwaters of the east fork of the South Fork Salmon River. Recreational use is estimated at 456,000 visitor-days per year. Approximately 66,000 acres of the Frank Church-River of No Return Wilderness are within the South Fork drainage. An additional 614,461 acres of the South Fork drainage are within inventoried roadless areas. Of the nonwilderness land, 59,515 acres are considered economically and physically suitable for timber harvest, with a long-term sustained yield capacity of 2,954,000 cubic feet per year.

Annual water yields for the basin average 1,661,000 acre-feet. Several permit applications have been filed for hydroelectric development. Current grazing is permitted at a level of 6,600 animal unit months per year. The South Fork drainage provides habitat for more than 200 species of birds. Resident large mammals include elk, mule and whitetail deer, black bear, cougar, mountain goat, moose, bighorn sheep, and the endangered Rocky Mountain gray wolf. The South Fork system supports fish populations of resident species, such as trout and char, and anadromous species including salmon and steelhead (USDA FS 1985).

The South Fork is considered particularly crucial as a source of spawning and rearing habitat for the anadromous fish populations. Historically, the South Fork supported Idaho's largest population of summer chinook salmon (Platts and Partridge 1983). The number of returning adults declined from an estimated high of 10,000 fish in the mid-1950's to an estimated low of 250 fish in 1979. The reduction in returning adult salmon led to the closure of a popular and economically important anadromous sport fishery on the South Fork in 1965. Downstream influences of commercial and sport fishing, as well as construction of eight mainstream hydroelectric dams on the Columbia and Snake Rivers, contributed to this decline. However, degradation of habitat conditions in the upriver spawning areas due to land-use activities was also a contributing factor.

Development of the South Fork drainage prior to 1940 included intensive mining and grazing. Mining activities were responsible for significant deposits of sediment and chemicals to the stream system, while uncontrolled grazing contributed to increased sediment loads and degradation of riparian areas. From 1945 to 1965, intensive logging activities resulted in dense road networks and other sources of accelerated sedimentation (USDA FS 1985).

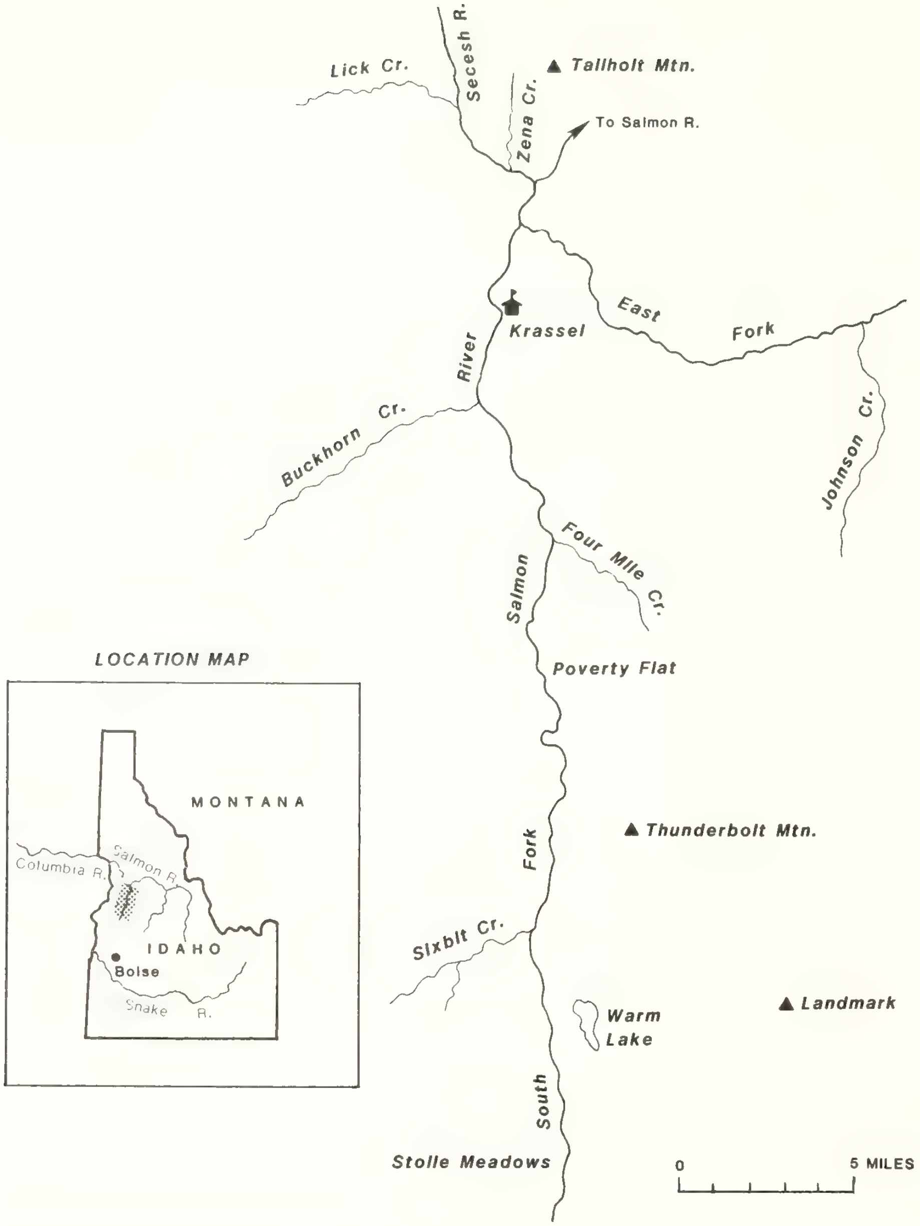


Figure 1—South Fork of the Salmon River. Inset shows the South Fork's placement in Idaho's major river systems.

Extreme climatic events in 1964 and 1965 produced disastrous results for fish habitat. Massive amounts of sediments, up to 1,500,000 cubic yards annually, were introduced to the stream system (Platts 1970). As sediment production reached its peak historical level (162 percent of natural), anadromous fish production decreased to its lowest level, 20 percent of potential (USDA FS 1985).

In 1965 a moratorium on logging and road construction was imposed in the South Fork Planning Unit. This unit is the largest (348,800 acres) of five major subdivisions of the South Fork drainage basin and contains the majority of the spawning and rearing habitat used by anadromous species in the South Fork system. It includes most of the main stem of the South Fork, plus parts of the east fork of the South Fork and Secesh River drainages. Prior to the moratorium, the unit was heavily developed by logging activities, with approximately 800 miles of roads and an average annual timber harvest of 16 million board feet (USDA FS 1985). A watershed rehabilitation program was implemented in conjunction with the moratorium (Megahan and others 1980).

Research results in the years following the declaration of the moratorium showed a gradual recovery of the fish habitat as indicated by changes in streambed elevation and in average particle size of streambed substrates (Megahan and others 1980). In 1978, a 10-year Land Management Plan was implemented on the South Fork Planning Unit. The plan recognized the anadromous salmonids as the most valuable resource of the unit and conditioned all land disturbance on continued habitat improvement. Manage-

ment activities (primarily associated with timber harvest) were planned with a constraint that accelerated sedimentation due to the activities could not reverse the improving trend in fishery habitat conditions. Efforts were made to minimize disturbance to soil and streams, reduce erosion on disturbed areas, provide sediment buffer zones, and schedule disturbances so as to disperse the resultant sediment to streams in space and time. Three planning levels placed more specific restrictions on activities to accomplish these goals (Cole and Megahan 1980).

A comprehensive monitoring program was implemented to evaluate the effects of management activities through studies conducted at project sites, in tributary streams, and in the main stem of the South Fork. Timely feedback to land managers regarding existing or potential problems was an integral part of the monitoring process. In addition, the South Fork Salmon River Monitoring Committee, consisting of soil, water, and aquatic specialists from various concerned agencies and organizations, was established to review monitoring results and make recommendations (Cole and Megahan 1980). The early monitoring efforts showed few major impacts from new land-use activities and evidences of habitat improvement (South Fork Salmon River Monitoring Committee 1979, 1980, 1981, 1982, 1983). However, in 1984, based on the recommendation of the committee, sediment-producing land disturbances were halted temporarily. This was largely due to the failure of some of the spawning areas to show continued improvement (USDA FS 1985). The recommendation was repeated in 1985 and 1986. No improvement in aquatic habitat was expected under the existing conditions, as the system appeared to be approaching a new equilibrium (South Fork Salmon River Monitoring Committee 1985, 1986). Sediment rates were stabilizing at about 113 percent of natural, and anadromous fish habitat was estimated to be 55 percent of potential. A hatchery program, improved downstream fish passage, and other mitigating measures are contributing to increasing fish populations (USDA FS 1985).

HOW TO ORDER PUBLICATIONS

This bibliography includes annotations of relevant published and unpublished reports on fishery and hydrology studies conducted in the South Fork of the Salmon River drainage. Microfiche copies of all references cited in this bibliography are on file in the library of the Intermountain Research Station. To order, please write to:

Library
Intermountain Research Station
Forest Service
U.S. Department of Agriculture
324 25th Street
Ogden, UT 84401

Orders may also be made by phoning (801) 625-5444.

BIBLIOGRAPHY

Arnold, John F.; Lundeen, Lloyd J. 1968. South Fork Salmon River special survey, soils and hydrology. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise National Forest. 195 p.

This special study, initiated in 1965 as a cooperative effort between the Forest Service and Idaho Fish and Game Department, evaluates the causes and impacts of recent severe sedimentation on the subject stream. The area surveyed, approximately 254,000 acres, includes all of Cascade Ranger District, Boise National Forest, within the South Fork Salmon River drainage and on the Krassel Ranger District, Payette National Forest, that same drainage, down to the mouth of the east fork of the South Fork, and in addition, the Zena Creek Sale Area and the Secesh River face downstream from Lick Creek.

The report identifies the main sources of sediment production within the South Fork and evaluates the relative amounts of sediment produced in each drainage and its source location. The study area is stratified using the landtype concept as in the Zena Creek Report (Jensen and Finn 1966). Different soils for each mapping unit are identified, and interpretations of the capabilities, potentials, and hazards are made for each unit. Each type and its most important limiting factors are evaluated. Lands are grouped by origin into four categories: strongly glaciated lands, periglaciated lands, stream cut lands, and depositional lands. The South Fork had an annual sediment production of over 92,000 cubic yards with about 22,000 cubic yards of this amount accruing from natural sources. Of the other 70,000 cubic yards, 64,000 are attributed to roads and skid trails. Over 70 percent of the total sediment is produced on the stream cut lands, which make up only 45 percent of the area.

Estimates place the amount of sediment in the channel system at nearly 2 million cubic yards. The river is able to export only about 35,000 cubic yards on an annual basis, so that even if sediment production is reduced to a near natural level, it will take many years for the river to cleanse itself. (Annotation from Skabelund 1970.)

Bethlahmy, Nedavia. 1965. Untitled progress report on 1964 watershed management research, Zena Creek logging study. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 3 p.

Based on 2 years of data, Tailholt Creek yields about 1.5 times more water and sediment per unit area than Circle End Creek. Water yields on the two watersheds for water years 1963 and 1964 range from 7.97 to 13.20 inches. Bedload sediment values for roughly the same period range from 71.2 to 130.6 pounds per square mile per day.

Sediment yields for September 1963 to September 1964 from the Deep Creek logging compartment show that on 0.01-acre plots 118 and 122 pounds per acre occurred on the jammer and high-lead areas, respectively. In natural waterways, the measured values are 81 pounds per acre for jammer areas and 12 pounds per acre for high-lead areas. The term "high-lead area" might be deceptive because the logs in that area were removed with high-lead equipment, but were dragged downhill. Analysis of the plot data from May 1962 to September 1964 also confirms the results of a previous study that suggested that runoff and erosion during high-intensity storms were greater on southwest than on northeast slopes (see Bethlahmy 1967; Bethlahmy and Kidd 1964). The data show that the timing

of erosion processes also differs on the two exposures. Summer-fall erosion rates are greater than winter-spring erosion rates on the southwest aspects, but the rates are fairly uniform for the two periods on the northerly aspects. The data do not indicate any increase in erosion rates associated with logging, aside from that which could be attributed to logging roads.

Bethlahmy, Nedavia. 1967. Effect of exposure and logging on runoff and erosion. Res. Note INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 7 p.

Runoff and erosion from 32 plots in the Zena Creek Logging Sale Area were monitored during 30-minute artificial applications of high-intensity rainfall (average 12.2 cm/h). Plots were chosen to yield equal numbers of northeast and southwest exposures, and of logged and unlogged areas. Average runoff values vary from 0.54 cm/30 min on logged northeast exposures to 3.72 cm/30 min on logged southwest exposures. Average sediment yields varied from 2.9 g/30 min on unlogged northeast exposures to 170.6 g/30 min on logged southwest exposures. Erosion is a logarithmic function of runoff. Runoff and erosion are significantly greater on southwest exposures than on northeast exposures, and significantly greater on logged plots than on unlogged plots for southwest exposures only. Runoff is directly related to percentage of bare soil. Differences in erosion rates are partially explained by differences in slope gradient and in percentage of bare soil. Management implications are included.

Bethlahmy, Nedavia; Kidd, W. Joe, Jr. 1963. 1602 - soil stabilization project. In: Semiannual report, Division of Watershed Management Research, April-September 1963. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT: 9-12 (p. 9-11).

In the Deep Creek logging compartments of the Zena Creek study area, sediment yields following fall 1962 logging were measured using small watershed dams and 1/100-acre plots. In the jammer logging area, the measured value at the dams is 213 tons per square mile for the period from May 28 to July 18, 1963, all attributable to fill slope erosion. In the mobile spar-skyline crane logging area, the corresponding value is 25 tons per square mile and represents skid trail erosion. Sediment yields for roughly the same period from the erosion plots are 7.8 and 17.3 tons per square mile for the jammer and mobile spar-skyline crane areas, respectively. Prior to logging, yields from the plots were zero. Data from the unlogged Oompaul Creek compartments for May 28 through September 12, 1963, show no sediment in the small watershed dams, and values of 16.3 and 22.4 tons per square mile for the plots in the jammer and mobile spar-skyline crane areas, respectively. Erosion on the Oompaul plots is attributed primarily to rain splash and gopher activity.

During the 1963 peak flow of March 21 to April 25, average suspended sediment concentrations in Tailholt and Circle End Creeks are 64 and 37 parts per million, respectively. Bedload sediment yields for May 15 to September 4, 1963, are also greater for Tailholt (8.2 tons per square mile) than for Circle End (2.2 tons per square mile).

This report contains some tentative results of a study to measure physical and chemical characteristics of road fill slopes. (See Ohlander 1964 for final results of the study.)

Studies of soil moisture in exposed areas at 5,200 feet show that both north- and south-exposure soils dry out beyond their wilting points during the summer. The southern exposure soils become drier than those on northern exposures. Data on percentage moisture at depths of 0 to 2, 5 to 7, and 11 to 13 inches are given for north and south exposures on five measurement dates beginning with June 26, 1963, and ending with September 19, 1963. On June 26, percentage moisture values vary from 9.3 to 20; by August 29 all values are below 3. Values of water-holding characteristics at one-third atmosphere (measured at the same depths as given above) vary from 4.4 to 8.1 percent moisture and are consistently higher on the north slopes. For 15 atmospheres the range is 2.2 to 5 percent moisture, with the samples from the northern exposures again having higher values than those from southern exposures at comparable depths.

Preliminary results from an infiltrometer study suggest that runoff is much greater on southwest slopes than on northeast slopes, and also higher on logged southwest slopes than on unlogged southwest slopes. (See Bethlahmy 1967 for the final report on this study.)

Infiltration tests on roads show that, on fully benched roads, runoff is greater from the edge than from the center; however, the rates are similar from edge and center where the road is composed wholly of fill material.

Bethlahmy, N.; Kidd, W. J., Jr. 1964. Zena Creek logging study: progress report - 1963. Highlights of watershed management research activities. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 8 p.

Analyses of 5 years of precipitation data from the Zena Creek study area give the following values of storm characteristics for respective return periods of 1, 5, and 10 years: 2.1, 3.5, and 4.2 inches total rain; 48, 72, and 84 hours duration; 2.5, 4.0, and 4.8 inches per hour maximum intensity (for any interval). All of the values are based on a certainty of 0.5; doubling the return period would yield 100 percent reliability. (See Kidd 1964 for the final report on this study.)

Statistical analyses of hydrograph responses to 47 storms occurring between September 1962 and November 1963 show that the variables of time to peak, total rise in stage, and stage on the rising limb are highly correlated on Tailholt and Circle End Creeks. Rising limb stages on the two creeks are described by the relation $T = 1.042C + 0.700$ (where T = Tailholt stage and C = Circle End stage).

Infiltration measurements on the Oompaul Road demonstrate that the road center is more impervious than the road edge, particularly on cut sections. Nonuniform compaction is the cause.

Studies on forested areas show that both runoff and erosion are much greater on southwest than on northeast exposures. Rainfall of 30 minutes results in an average of 1.3 grams of eroded material per plot on northeast sites, 5.1 grams on unlogged southwest plots, and 88.1 grams on

logged southwest plots. Values of runoff as a percentage of applied precipitation are 7 for logged northeast, 15 for unlogged northeast, 62 for logged southwest, and 32 for unlogged southwest plots.

Postlogging erosion measurements for May 28 to July 16, 1963, in the small watersheds in the Deep Creek compartments, yield values of 213 and 25 tons per square mile on jammer and mobile spar-skyline crane areas, respectively. Small plot studies give respective values of 7.8 and 17.3 tons per square mile for jammer and mobile spar-skyline crane areas. Prelogging erosion values for the small watershed and small plot studies were zero. The skyline crane was used incorrectly by the logger, and so the measured values may be misleading.

Bjornn, T. C. 1971. Abundance of chinook salmon as related to sediment in the South Fork of the Salmon River. Unpublished paper on file at: University of Idaho, Department of Fishery Management, Moscow, ID. Unnumbered pages.

By comparing the abundance of salmon redds since 1951, the author attempts to gauge the effects of massive sediment introductions, associated with poor logging practices and climatological events, to the South Fork Salmon River during the mid-1960's. Although chinook salmon entering the Columbia River system have decreased steadily since the late 1950's, thus complicating specific analysis of a particular stream, the author presents compelling evidence documenting the decline in abundance of chinook salmon. Because downstream (hydroelectric dams, sport, and commercial fishing) reductions in spawners is assumed as nondiscriminatory toward stocks, comparison of South Fork chinook abundance with those of tributaries not affected by sediment loading will elucidate those effects. Comparisons between redds in the South Fork and those in other less sedimented streams in the drainage indicate the rate of decline in the South Fork proper exceeds the decline in other tributaries in the drainage. The author concludes that the South Fork in its present condition may be able to support the small runs entering the river, but could not provide adequate spawning and rearing areas for the larger runs of past years.

Brusven, M. A.; Gilpin, B. R. 1975. Benthic community dynamics in relation to sedimentary rehabilitation on tributaries of the South Fork of the Salmon River. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 119 p.

This study provides data on species composition, density, recolonization, and habits of aquatic invertebrates through changing stream habitat before, during, and after watershed rehabilitation in three tributaries of the South Fork Salmon River.

Burns, David C. 1984. An inventory of embeddedness of salmonid habitat in the South Fork Salmon River Drainage, Idaho. Boise and McCall, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 30 p.

The author compares fisheries habitat as measured by substrate embeddedness in "developed" and undeveloped watersheds of the South Fork Salmon River. Developed (roaded and logged) watersheds have significantly higher embeddedness ratings. The highest level of embeddedness was measured in Sugar Creek, immediately downstream from an open-pit mine. The data indicate that a threshold of development exists that, if surpassed, could significantly impact fisheries habitat.

Burns, D. C. 1987. Embeddedness of salmonid habitat of selected streams on the Payette National Forest 1985-1986. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Payette National Forest, McCall, ID. 20 p.

This study is a continuation of the author's 1985 work concerning substrate embeddedness levels in the South Fork Salmon River. Four separate areas are analyzed for trends in embeddedness: Thunder Mountain Mining Area, Stibnite Mining Area, South Fork Salmon River, and the Chamberlain Creek drainage. Improving trends are noted in the Stibnite Mining Area and in the South Fork Salmon River drainage. Other areas show little change from 1985 levels.

Burns, David C.; Edwards, Richard E. 1985. Embeddedness of salmonid habitat of selected streams on the Payette National Forest. McCall, ID: U.S. Department of Agriculture, Forest Service, Payette National Forest. 40 p.

To better manage the fisheries habitat within the Payette National Forest, substrate embeddedness is evaluated on a number of Forest streams, including seven locations on the main stem South Fork Salmon River.

Clayton, James L.; Larson, Kermit N. 1969. Soil, vegetation and hydrologic survey of Tailholt and Circle End Creeks. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. Unnumbered pages.

For 34 mapping units in the Circle End and Tailholt watersheds, the authors evaluate several variables, including general site descriptors, bedrock and soil characteristics, vegetative composition, drainage network attributes, and erosional/depositional features.

They find nine soil series of the Mollisol (now classified as Inceptisol) and Entisol orders. Soil textures include loamy sands, sandy loams, and loamy coarse sands. Soil depths range from 10 to 50 inches. Soil cover by litter and vegetation is generally in excess of 50 percent. Quartz monzonite is the dominant bedrock. Pegmatite, aplite, andesite, granite, and alluvial materials are also represented. Bedrock textures are predominantly medium-grained. Most of the bedrock is placed in weathering classes 3, 4, and 5 (on a scale from 1 to 7). All bedrock fracturing classes are well represented.

Spacing between drainages ranges from 100 to 1,000 feet, while drainage depths (relative to adjacent ridgelines) are 200 feet on the main drainages and up to 30 feet elsewhere. Percentages of each unit undergoing active surface erosion vary from 0 to 100, with a median value around 80. Erosion is commonly attributed to lack of vegetative cover, steep slopes, game trails, and fire. The authors cite other factors: rodent activity, presence of hiking trails, ice action, local disturbances, concentration of water in

stream channels, shallow soils, and runoff from rock outcrops. Most units have no significant impediments to sediment delivery to channels, although in a few cases vegetation or rock formations provide barriers.

Clayton, James L.; Megahan, Walter F.; Hampton, Delon. 1979. Soil and bedrock properties: weathering and alteration products and processes in the Idaho batholith. Res. Pap. INT-237. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 35 p.

The degree of weathering of batholithic rocks, as described by a previously devised seven-class system, appears to reasonably reflect physical and mineralogic changes in bedrock. The authors observe these changes in hand specimen, thin section, and through chemical, physical, and x-ray analyses of fresh and weathered bedrock from 29 sites in the Idaho batholith, including one at Zena Creek and one at Lick Creek.

After the unloading associated with overburden erosion, initial hydrolysis and oxidation of biotites provide sufficient pathways for water entry, a necessary precursor to physical weathering. Rocks at or near the ground surface then progressively weather to grus, with physical weathering processes dominating chemical weathering. At depth, chemical weathering processes assume greater importance, and the products of chemical weathering are better preserved. Biotites commonly weather to a degraded mica, then to a smectite-iddingsite product, and eventually to a 10-angstrom clay, probably illite. Sericitic weathering products and, ultimately, kaolinization of feldspars are common.

Relationships between soil morphologic properties and bedrock weathering in the Idaho batholith are for the most part obscured by climatic and topographic influences, such as precipitation patterns, slope steepness, and internal soil drainage.

Slope steepness affects erosion rates, and erosion strongly controls the time for pedogenic processes to differentiate soil horizons. Batholith soils are predominantly Entisols, Inceptisols, and weakly developed Alfisols and Mollisols, all reflecting lack of pedogenic development due to high erosion rates. (Adapted from authors' summary.)

Cole, Gene F.; Megahan, Walter F. 1980. South Fork Salmon River—future management. In: Proceedings, symposium on watershed management; 1980 July 21-23; Boise, ID. New York: American Society of Civil Engineers: 396-405. Vol. 1 of 2 vol.

The planned management of the 545 square miles of National Forest System Land in the South Fork Salmon River planning unit includes management directions and environmental policies. These are discussed as related to the goal of maintaining the trend of improvement of the salmon spawning areas.

Corley, Donald R. 1976. Fishery habitat survey of the South Fork Salmon River—1975. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 70 p.

This report is the first in a series summarizing the fishery habitat condition of the South Fork Salmon River. The purpose of these reports is to trace the rehabilitative process in a watershed badly damaged by land management activities. The physical structure of the river, streambed substrate composition, and juvenile fish populations are evaluated. Habitat condition is satisfactory for spawning of chinook salmon in the Stolle Meadows area, while high levels of fine sediment are severely impacting the Poverty, Krassel, and Glory spawning areas.

Corley, Donald R.; Burmeister, Lyle A. 1978. Fishery habitat survey of the South Fork Salmon River—1977. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 90 p.

This is the second in the series of reports designed to monitor fishery condition of the South Fork Salmon River. Physical rearing areas are improving. Conversely, spawning habitat has improved little, with large volumes of fine sediments continuing to impact downstream spawning areas.

Corley, Donald R.; Burmeister, Lyle A. 1980. Fishery habitat survey of the South Fork Salmon River—1979. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 79 p.

This third report in the series indicates that fishery condition continues to be impacted by massive amounts of fine sediment in lower spawning reaches of the South Fork Salmon River. Spawning conditions range from good in the Stolle Meadows area to poor at the Poverty, Oxbow, and Glory areas.

Corley, Donald R.; Newberry, Donald D. 1982. Fishery habitat survey of the South Fork Salmon River—1981. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 83 p.

The fourth in the series of reports investigates the physical structure, streambed composition, and juvenile fish populations of the South Fork Salmon River. Streambed core samples indicate a continuing trend in fine sediment reduction. Snorkel surveys show juvenile salmon to be a fourth as abundant in 1981 as in 1979. Measurements of rearing pool width and volume, and riffle area vary considerably, indicating a need for improved methodology.

Note: The fifth publication in this series is by Newberry and Corley (1984).

Craddock, George W. 1967. Zena Creek logging study evaluation report. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region and Intermountain Forest and Range Experiment Station. 63 p.

This report pulls together all of the available information on the Zena Creek logging study (1959 to 1966), to provide an historical account of the progress of the various phases of the study and to evaluate the overall achievement and failures of the study at the termination of the timber sale contract. Included are a background, a brief history of the study, and a review of the initial study objectives and how these objectives evolved during the course of the study. Logging and road construction activities associated with the timber sale are described here in quantitative and qualitative terms. Administrative and

research studies are outlined, as well as some of the study results. The evaluation summary gives an overview of the ambitious and complex study that encountered many difficulties, but from which much is learned. The administrative and research studies provide a wealth of new information to land managers working in the batholith, but research has not been part of the planning process. The logging operations have experienced considerable difficulties in terms of road failures and shortcomings of the equipment, but efficiency has improved over the years, and mistakes have been recognized and corresponding adjustments made. It has become clear, however, that the logging system used in Zena Creek is not the ultimate answer for logging in the batholith. The author concludes:

> The Zena Creek Logging Study as a whole accomplished much toward a better understanding of the timber management possibilities on the steeply sloping lands of the Idaho batholith. The study demonstrated that timber can be harvested economically and without watershed damage on portions of the steeper lands by careful location and construction of logging roads and use of a mobile spar and aerial crane. It also demonstrated that some of the lands having shallow soil derived from decomposed granite are too unstable to withstand the disturbance of road construction. Therefore, unless some aerial cable system can be devised that will permit yarding logs at greater distances and without having to build roads across vulnerable slopes, it appears that some portions of the batholith should not be managed for timber production.

Curtis, James D. 1965. Zena Creek logging study. Progress report—1964. Timber management research. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 7 p. (p. 6).

Warm-season (June through September) precipitation totals at 5,000 feet in the Zena Creek area are, in inches, 5.72 in 1959, 2.31 in 1960, 2.62 in 1961, 4.24 in 1962, 7.13 in 1963, and 8.77 in 1964, with an average value of 5.13. The 6-year averages by month are, in inches, 2.22 for June, 0.42 for July, 0.91 for August, and 1.58 for September.

Gardner, R. B.; Hartsog, William S.; Dye, Kelly B. 1978. Road design guidelines for the Idaho batholith based on the China Glenn road study. Res. Pap. INT-204. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 20 p.

This paper is a follow-up to one by Hartsog and Gonsior (1973). Performance of the China Glenn Road, which was designed for minimum environmental impact, is reassessed 6 years after the initial construction and 5 years after the second phase of construction. In the second phase, the road was extended and design criteria refined based on the results of the initial construction. The authors are generally impressed with the performance of the initially constructed portion of the road. Revegetation of cuts and fills is good, drainage features are functioning well, and no slope failures have occurred. For the second phase of construction, the area disturbed is lessened, fewer culverts are installed in minor draws, a modified dip design is implemented, and drainage during construction is allowed for in the design. The authors find that the road is very stable and that the goal of minimum impact has been achieved.

Recommendations are made: Minimize clearing widths and road travel widths. Contour and roll grades in such a manner as to produce minimal disruption of natural drainage patterns and to minimize cut and fill areas. Design turnouts so that the area disturbed is minimized. Construct dips (perpendicular to the center line) during grading to control water during and after construction while minimizing effects on vehicles. Use a variety of drainage control features to regulate flows on roads without ditches. Use slash to help limit sediment movement from fills. Revegetate cuts and fills the first year following construction.

Gonsior, M. J.; Gardner, R. B. 1971. Investigation of slope failures in the Idaho batholith. Res. Pap. INT-97. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 34 p.

Severe but not unusual climatic events in the winter of 1964 to 1965 and in spring 1965 started a significant number of landslides in the Zena Creek drainage. Although some of the mass movement activity might have been expected under undisturbed conditions, roads are primarily responsible for the accelerated erosion processes. Studies conducted in 1967 use a variety of field and laboratory techniques to describe the soils and assess the causes of failure. Thirteen sites representing fill, cut, and natural hillslope failures, as well as those representing alluvial erosion processes and a stable embankment, are chosen for intensive study.

Failures are attributed to natural terrain instability, slope steepness (natural and artificial), poor drainage, and minimal fill compaction. Some fills include logs and stumps that contribute to instability. Sonic booms could also have adverse effects on stability.

Recommendations for future construction: Conduct stability analyses of fill slopes, and limit gradients on unretained fills to 70 percent. Build cut slopes as steep as possible, using slope rounding when necessary. Avoid deep fills or cuts or both by sacrificing alignment. Compact fill slopes based on evaluation of their material properties and design standards. Improve drainage to limit pore pressures in fills and cuts, and to limit surface runoff concentrations. Inslope and berm fill sections; check for adequacy of erosion protection on outsloped benched sections. Remove logs and debris from fill material. Revegetate fill slopes in a timely manner with suitable species; place materials at the fill slope toe to limit sediment movement. Stabilize roadbeds. Prevent movement of eroded cut slope material into live streams. Make necessary analyses of soil properties and of surface and subsurface water conditions prior to deciding road locations. Use multidisciplinary teams to minimize impacts on the functioning of the natural systems.

Hartsog, W. S.; Gonsior, M. J. 1973. Analysis of construction and initial performance of the China Glenn Road, Warren District, Payette National Forest. Gen. Tech. Rep. INT-5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

The China Glenn Road was constructed between July and September of 1970 to provide immediate access for a salvage timber sale in the K Creek, China Creek, and Big Flat Creek watersheds. It is the first new road to be constructed in the area in several years and is designed for minimum impact. Design features include outsloping, 90-foot minimum radius of curvature, intercepting dips, and riprapped culverts. In addition, the route is placed above the usual danger zone for rain-on-snow events and avoids traversing slopes in excess of 65 percent, while cut and fill slope gradients are limited to 100 and 67 percent, respectively.

Based on observations before and during construction, the authors make several recommendations: (1) Use specialized clearing equipment on steep slopes to alleviate the need for pioneer road construction. (2) Leave slash at fill slope toes to retain sediment whenever practical. (3) Construct fill slopes at angles less than the angle of repose and compact fill material thoroughly. (4) Avoid terracing on cuts and take measures during construction to reduce cutslope erosion. (5) Regulate sediment transport from cut and tread areas and design road surfaces to carry water. (6) Avoid use of dimpled connecting bands on culverts. Do not orient culverts perpendicular to the center line on extremely steep slopes. Take care in bedding of culverts and allow for camber without bending the pipe. In natural channels use backhoes rather than crawler tractors for culvert installation. Do not use saturated material for backfill, and compact properly. (7) Apply stabilization treatments as soon as construction is complete. (If the road will be used immediately, drainage features may need to be altered in the initial construction phase.) (8) Limit road widths, and heights of cuts and fills, sacrificing alignment when necessary and possible. Also limit the area in turnouts and turnarounds. (9) Find methods to accelerate revegetation of cuts and fills. (10) Foster improved communication between engineers and land managers. Provide for flexibility in adjusting construction contracts as desirable changes become apparent onsite.

Haupt, Harold F. 1963. Zena Creek logging study. Progress report - 1962. Watershed management research. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 4 p.

During water year 1962, both winter and summer precipitation were greater than during the preceding several years. Measured streamflow and sediment in Tailholt Creek show increases from the previous year. For example, bedload sediment yield increases from 8.6 to 14.8 tons per square mile, and the maximum instantaneous discharge increases from 1.81 to 2.76 cubic feet per second per square mile. During the summer of 1962, a control for Tailholt Creek was established at Circle End Creek. The 1962 summer bedload sediment yields at Circle End were negligible.

A major series of storms contributed between 7.5 and 10.0 inches of rainfall during 10 days in October. These storms, of low intensity but of long duration, caused severe damage to a newly constructed haul road on the Secesh face. Examination shows that insloping of roads is more effective than outsloping in erosion prevention (see Haupt and others 1963).

Prelogging measurements of sediment yields in headwater drainages without perennial flow show that road construction caused significant yield increases in the Deep Creek logging compartments but not in the Oompaul compartments. Preconstruction yields were zero in both areas. Following construction, yields on the three measured watersheds in the Deep Creek drainage increased to 12,416, 8,960, and 89.6 tons per square mile. The differences in yields are attributed to variability in road standards, especially drainage features.

Haupt, Harold F.; Kidd, Walter J., Jr. 1962. Zena Creek logging study report, 1961. Watershed management research. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 2 p.

Sediment measurements during water year 1961 showed bed and saltation load sediment yields of 8, 9.1, and 13.1 tons per square mile on Tailholt, Hamilton, and Oompaul Creeks, respectively. Suspended loads were negligible during peak runoff. The high bedload rate on Oompaul Creek is attributed to a 1955 rain-on-snow event in which 360 cubic yards of sediment from a land slump were deposited into the stream channel. The sediment had caused temporary ponding, and then was released forcefully into the system that previously had had a stable bottom. Such phenomena are not uncommon in the area.

Haupt, H. F.; Rickard, H. C.; Finn, L. E. 1963. Effect of severe rainstorms on insloped and outsloped roads. Res. Note INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.

Damages to insloped and outsloped portions of a newly built, secondary logging road in the Zena Creek logging study area are evaluated following a series of long-duration, low-intensity storms. The road, built in June 1962, goes across west and southwest slopes with gradients in excess of 60 percent. Cut slopes are generally 8 to 14 feet high and composed of granite overlain by soils that are very coarse, sandy, and shallow (less than 20 inches in depth). In September 1962, shoulders and fills were seeded, and covered with hay and asphalt binder.

During 10 days in October 1962, the road was impacted by three storms with durations of 8, 38, and 87 hours. Storm intensities did not exceed 0.20 inches per hour for any hour, or 0.48 inches per hour for any 10-minute period. Measured values of total precipitation due to these storms vary from 7.60 to 9.99 inches at rain gauges in the area. This total is unprecedented in over 50 years of record at McCall.

Soils above the road were saturated early in the storm period, and large amounts of subsurface flow were

generated. In swales, channel flow also occurred. No culvert failures due to plugging were observed. Damage is much greater on outsloped road sections than on insloped sections. Runoff onto the fills of outsloped sections resulted in considerable erosion, slumpage, and sediment movement, with the greatest damage at incurves. Little erosion of road cut and tread occurs on insloped sections, and severe fill damage occurs only at cross-drains and at swales. The authors conclude that

> Insloping. . .is more desirable than outsloping as a measure for preventing erosion. Specifically, the inslope should be designed to lead as much storm runoff as possible away from the long fill on the incurve of the road. Where culverts are to be used in major ravines, they should be located on the original water grade so that they do not discharge on the fill of the incurve but drain into the original channel. Where earthen cross drains are to be used, they should be located to discharge their flows on the outcurve of the road. Below the outcurve the undisturbed side slope will tend to absorb road drainage and retard sediment flows before they reach a ravine or stream.

The Idaho Citizen. 1977. Sediment and salmon on the South Fork. October-November: 24-27.

This article documents the effects of erosion from logging unstable watersheds in the South Fork Salmon River. Sediment levels moving into the river average 70,000 cubic yards greater than in the undisturbed watershed. Although the stream and watershed have initially recovered, the Forest Service plans to log up to 12 million board feet of timber per year. Included are management viewpoints of interested parties, including the Forest Service, Idaho Fish and Game Department, Boise-Cascade Corporation, Idaho Wildlife Federation, and private citizens.

Jensen, Frank R.; Cole, Gene F. 1963. Restoration (Poverty Burn). Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest, McCall, ID. 4 p.

This report documents the history of the Poverty Burn and the efforts made to rehabilitate the area and prevent sedimentation into the South Fork Salmon River. It appraises the various treatments as to cost and success. Treatments evaluated are contour trenching, salvage logging, grass seeding, contour tree felling, and check dams. The most successful treatment of burned areas on this type of landscape would be aerial seeding a mixture of perennial and annual grasses and avoiding disturbance of the burned area in general, either by contour trenching or salvage logging (road building) activities. Salvage areas should be studied carefully to determine what portions of the areas can be logged and still meet watershed stability requirements. (Annotation from Skabelund 1970.)

Jensen, Frank R.; Cole, Gene F. 1965. South Fork of the Salmon River storm and flood report. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest, McCall, ID.

Two periods of severe watershed damage occurred during the winter of 1964-65 in the South Fork of the Salmon River drainage. The climatic conditions, damages, impacts, and causes associated with the events of that winter are investigated on the Krassel Ranger District.

The first period of damage is associated with the "Christmas Storm" of December and January. In those months about 11 inches of precipitation fell, mostly as rain, on a snowpack with moisture contents of 3 to 6 inches, which was already melting due to mild weather. About 5 to 6 inches of runoff were generated in a relatively short time. The combined effect of the precipitation and snowmelt is on the order of a 30-year to 40-year event. Damages include more than 400 slumps on undisturbed slopes, about 50 road undercuts, a major "blowout" of the Poverty Burn area, and "blowouts" of about 50 side stream channels. Over 100,000 cubic yards of sediment reached the channels, with 45 percent from the Poverty Burn, 30 percent from stream blowouts, 20 percent from roads, and 5 percent from natural slumps. Impacts to recreation, timber, and big game are relatively minor. The major impacts are to roads (repair costs in excess of $35,000) and to the fisheries (more than 6 inches of sand covers most of the spawning gravels and many holes are filled with sand). Most of the damage other than that attributed to the Poverty Burn blowout would probably have occurred naturally. Contour trenching and road construction on the Poverty Burn are primarily responsible for the erosion there.

In April, 3.40 inches of precipitation fell, with 1.03 inches in 1 day during the peak snowmelt period. A total of 89 landslides were surveyed. Of these, 77 percent originated on fillslopes. Certain conditions of soil, moisture, physical position, and slope gradient are involved in all the slides. The total volume of sediment from these slides is 277,400 cubic yards, of which 50 percent was deposited into live streams at the time of the survey. This further contributes to the degradation of the fishery resource. Many channels are scoured to bedrock, which will change the hydrology of the area, making it more susceptible to flooding. Cost of road repairs is in excess of $50,000; cost of repairs plus stabilization, in excess of $200,000. In addition, 100,000 board feet of timber was transported with little chance of salvage. Impacts to recreation and wildlife, aside from those already mentioned, are expected to be minor. The authors attribute most of the April damages to road construction.

The authors recommend extreme caution for future road construction and logging operations and propose some conservative design criteria for roads in the area. They discourage future contour trenching of burned areas and suggest some rehabilitation measures.

Jensen, Frank; Finn, Larry. 1966. Hydrologic analysis of the Zena Creek logging study area. McCall, ID: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest. 123 p.

Undertaken in 1966 at the request of the Zena Creek Logging Study Committee, this study evaluates watershed conditions at the termination of the timber sale. The original questions prompting the Zena Creek Logging Study are addressed based on a review of previous research data and a reconnaissance of the area.

The five major landtypes on the study area are described in terms of their geologic origin, physical characteristics, and multiple-use capabilities. The sedimentation for any given watershed in the area is directly proportional to the mileage of roads in the watershed on the decomposed granitic landtype. Of the total sedimentation due to roads occurring from the time of inception of the Zena Creek study to the time that the hydrologic analysis was made (127,855 cubic yards), 99.2 percent had originated on the decomposed granitic lands, which contain 80 percent of the total road length of 29.04 miles. Most of the sediment from the road system had reached the streams by the time of the hydrologic analysis. The authors recommend that construction of new roads in this landtype be restricted to ridge tops and to slopes less than 45 percent unless artificial stabilization measures are taken. They also recommend that existing roads in the landtype be put to bed wherever possible. Lesser modifications in road construction practices to allow for the special characteristics of the periglacial and river terrace landtypes are also suggested.

The report contains data on precipitation, water yields, and peak flows, and information on damages from the three major storms that occurred during the course of the Zena Creek study. In the unroaded state, only two of the hydrologic types on the study area would yield runoff from a 1.5-inch, 6-hour storm (25-year storm). The authors recommend that all engineering structures be designed to accommodate storm events with a 25-year return period.

Of a total timber resource of 130 million board feet on the study area, 38,454 thousand board feet were removed (with economic gain to the contractor) during the course of the Zena Creek study. There is little evidence of watershed damage due to logging activities other than that which is associated with access roads. The Skagit logging system represents a significant improvement over systems previously used, but is still inadequate for logging on the decomposed granite landtype due to the need for a supporting road system traversing the slopes. The authors recommend that logging systems requiring no roads or roads only on ridge tops be investigated. They question whether any logging should be allowed in areas where regeneration efforts are likely to fail. Successful regeneration has been achieved on the moister areas of some landtypes, but the record is poor on the decomposed granite landtype. Further research on regeneration is urged.

There are no significant watershed impacts due to wildlife use. Big game winter range use has likely been disrupted by the logging activities. The authors strongly recommend that winter range protection be given top priority in the future because it involves a relatively small area but an important resource.

The authors feel strongly that the landtype concept is useful and should be the basis of all future multiple-use planning, resource inventories, and quotas, not just in the study area, but throughout the Krassel Ranger District.

Kidd, W. J., Jr. 1963. Soil erosion control structures on skidtrails. Res. Pap. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.

Between 1953 and 1955, erosion control treatments were installed on 105 skidtrails on four timber sale areas in central Idaho (including Martins Creek on the Krassel Ranger District). Three of the study areas are in the granitic materials of the Idaho batholith; one is in the Columbia River basalts. Treatments include slash dams, diagonal log water bars, cross-ditches, and lopped and scattered slash. In 1955, quantitative measurements of effectiveness of the various treatments are made; qualitative measurements are made in 1957. The weather potential for erosion between the time of installation of the treatments and the time of evaluation is moderate.

Greater erosion rates and slower recovery occur on the granitic soils. Trails in ravines have more erosion than those on sidehills. Erosion increases as spacing between structures increases. Optimal spacing recommendations are made based on parent material, slope gradient, and slope position. Log water bars and cross-ditches, which diverted the flow of water, are more effective in erosion control than are the two slash treatments, which only filter sediment and retard the flow of water.

Kidd, W. Joe, Jr. 1964. Probable return periods of rainstorms in central Idaho. Res. Note INT-28. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 8 p.

Five years (1959-63) of rainfall data from the Zena Creek sale area are analyzed statistically to yield return periods (at the 50 percent reliability level) for various events. Total rainfall, duration, and maximum intensities for specified periods are analyzed for 229 rainstorms as recorded at seven gauges at elevations ranging from 4,200 to 6,400 feet. Average total annual precipitation is 28.74 inches, of which approximately 45 percent falls as rain each year.

Storms with total rainfalls of 2, 3, 4, 5, and 6 inches have return periods of about 2, 3, 8, 23, and 60 years, respectively. Storm durations of 24, 48, 72, 96, and 120 hours have respective return periods of about 2, 3, 5, 22, and 105 years. Maximum 15-minute intensities of 1, 2, and 3 inches per hour have return periods of about 0.5, 1.6, and 3.8 years, respectively. Maximum 1- to 15-minute intensities of 1, 2, 3, 4, 5, and 6 inches per hour have corresponding return periods of about 1, 1.5, 2, 5, 13, and 35 years.

The maximum recorded intensity for a 10-minute period is about 2.7 inches per hour; for a 20-minute period it is about 1.4 inches per hour. Maximum recorded intensities for periods of 30 minutes or longer are all less than 1 inch per hour. The highest intensity on record is about 6.3 inches per hour for a period of less than 5 minutes.

Plotting of storm duration vs. rainfall shows that storms of 20, 40, 60, 80, and 100 hours duration have average rainfalls of about 0.8, 1.8, 2.7, 3.7, and 4.6 inches, respectively. The number of storms in various classes of depth, duration, and intensity are tabulated by month of occurrence.

Kidd, W. J., Jr.; Haupt, H. F. 1961. Soil erosion and soil stability as affected by harvesting ponderosa pine by different logging methods. Unpublished study plan on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 16 p. (p. 4-5).

Prelogging measurements of precipitation, sediment, and streamflow in the Zena Creek area were made in 1959 and 1960. Average total precipitation during the first water year of measurement is 29.4 inches, with the highest 5-minute intensity occurring at a rate of 3 inches per hour. Summer precipitation totaled about 4 inches in 1959 and 6.7 inches in 1960. Sediment measurements in the spring of 1960 on Oompaul, Hamilton, and Tailholt Creeks showed suspended loads during peak flows to be less than 225 p/m. However, springtime bedload rates are appreciable. These vary from 52 to 1,169 pounds per watershed per day (or from 0.10 to 0.74 pounds per acre of watershed per day), and are quite variable on different measurement dates and on different drainages.

Kidd, W. Joe, Jr.; Haupt, Harold F. 1962. Upstream sediment production as influenced by logging method. Unpublished study plan on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 13 p. (p. 3)

Precipitation measurements were made in the Zena Creek area in 1959, 1960, and 1961. Average total precipitation at 6,400 feet was 29.4 inches during the first water year of measurement, and 29.7 inches during the second. The greatest 5-minute intensity was 3 inches per hour. Warm season (June through September) rains contributed 5.75 inches in 1959, 2.20 inches in 1960, and 2.59 inches in 1961.

Knight, Charles A.; Thompson, Richard A.; Kulesza, Norbert C.; Dean, Edward N. 1974. Soil-hydrologic reconnaissance, Big Creek Ranger District, Payette National Forest. McCall, ID: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest. 211 p.

This report uses the same format, and much of the same information, as the reports by similar names for the Krassel Ranger District and the Cascade Ranger District (USDA FS 1969, 1970). It also draws on the South Fork Salmon River Special Survey, Soils and Hydrology Report (Arnold and Lundeen 1968).

The basic unit of the report is the landtype, of which 41 are identified on the District. These are grouped into eight geomorphic categories. Strongly glaciated lands include six landtypes and make up 27.1 percent of the total area; granitic glacial trough lands, nine landtypes and 35.2 percent of the area; volcanic glacial trough lands, one landtype and 1.3 percent of the area; cryoplanated granitic lands, six landtypes and 18.3 percent of the area; fluvial granitic lands, four landtypes and 3.3 percent of the area; fluvial volcanic lands, two landtypes and 1.6 percent of the area; steep granitic canyon slopes, seven landtypes and 6.8 percent of the area; depositional lands, six landtypes and 6.4 percent of the area.

Lundeen, Lloyd J. 1968. South Fork Salmon River special survey - stabilization survey. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest, McCall, ID. 10 p. plus graphs.

This survey's purpose is to determine more accurately the sediment sources within the same areas included in the South Fork Report by Arnold and Lundeen (1968). Field crews identify and locate most individual sources and make suggested alternatives of treatment for each. Cost estimates for each alternative are made. The data are programmed for computer use, and the various alternatives of treatment are analyzed as to their cost per yard of sediment reduction. The report covers six levels of suggested treatment ranging from very little treatment to maximum reduction attainable, including high cost measures for slump treatment and cut-slope stabilization. Cost estimates range from $53,700 to $15,555,000.

Plan 5 comes closest to meeting the needs of restoration of the stream within an acceptable time. This alternative requires treatment on most untreated logging roads and skid trails, nearly all of the proposed debris basins, some stream channel improvement, sheep driveway restoration, and treatment of some of the main roads. This plan would reduce the sediment load in the river by 200,000 cubic yards annually. Estimated cost for this program is $5,165,450. The rehabilitation program proposed by the Region to the Washington Office (under 1440 memorandum dated May 20, 1969) calls for all items in plan 4, plus stabilization of the Trail Creek Highway and reconstruction and relocation of the South Fork Salmon River Road (674) from Forest Highway 22 to the Payette National Forest boundary. Cost of this proposal is $4,877,317. (Annotation from Skabelund 1970.)

Megahan, W. F. 1965. An evaluation of the change in hydrologic function of watersheds due to proposed model road construction and logging and logging road construction on the Zena Creek logging study area - Payette National Forest. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 45 p.

A proposal is made to construct a "model road" in the Zena Creek logging study area. The road would bisect two small drainages and would have a total length of about 1 mile. Logging and logging road construction would also be carried out on these two small watersheds.

Performance criteria are developed for the road. A hydrologic and soils investigation is made to evaluate the needs defined by the five performance criteria that apply to the hydrology of the area. (These define acceptable limits on: drainage discharge into natural channels, sediment deposits in live streams, cut and fill slope stability, road drainage design in terms of return period, and road surface rivulet depths.) Also, the author reviews existing roads through lands similar to those in the vicinity of the model road to see how they reacted in terms of the performance criteria. None of the portions of the existing roads examined meet all five of the performance criteria; in fact, few of them meet any of the criteria.

Calculations of runoff volume, rate, and sedimentation are made for each of the two watersheds (1) under existing conditions, (2) with the model road, and (3) with logging and logging road construction. Calculations are made for various frequency storms. Without exception, runoff volumes and rates and sedimentation are increased by model road construction and more so by the planned logging operation. Most of the increases are due to road construction. The author feels that the increases due to logging would be erased in 5 to 10 years, while the increases due to road construction would be maintained permanently to some degree.

Although meeting the performance criteria is impossible, recommendations are made for complying with the criteria as closely as possible: (1) Use full bench construction wherever side slopes exceed 60 percent; do not sidecast. (2) Where sidecast is inevitable, or in fill sections, make sure there is an adequate protective strip below the road or provide artificial obstructions to prevent displaced material from entering the main streams as sediment. (3) Use surfacing on the road and road ditch. (4) Prevent air slacking or hold air slack material in place on cut slopes (this will probably require bin-walls). (5) Use mechanical and vegetative stabilization measures on fill slopes. (6) Compact all fills to the maximum to reduce the slump hazard. (7) Provide detention storage structures in the two drainages to precipitate sediment and to reduce flow rates. Be prepared to maintain the storage capacity of these structures. (Adapted from author's summary and conclusions.)

Megahan, Walter F. 1972. Volume weight of reservoir sediment in forested areas. Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers. 98 (HY8): 1335-1342.

A total of 90 surface and depth core samples was collected from 12 sediment detention reservoirs in spring 1969 and spring 1970 to evaluate volume weight characteristics. The reservoirs are at the mouths of small watersheds ranging in size from 0.1 to 2.5 square miles; the storage capacities of the reservoirs vary from 30 to 100 cubic yards. Water levels in the reservoirs are regulated by natural flow levels (with the exception of periodic flushing to maintain capacities). Five of the study watersheds (the A, B, C, and Main forks of Tailholt Creek plus Circle End Creek) are in the Zena Creek study area; the others are in the Silver Creek Study Area, which, like Zena Creek, is in the Idaho batholith.

The results of the laboratory analyses of the samples show a wide variation in the volume weights of samples both within and among the various reservoirs, even on the same measurement date. For example, the range of values in the 1969 data is from 8.7 to 103 pounds per cubic foot, and the average is 35.8 pounds per cubic foot. The variation is even greater in 1970 when the average is 67.9 pounds per cubic foot. Thus, it is apparent that the previously used practice of assigning an average volume weight of 90 pounds per cubic foot to all samples is highly inadequate, and that even intensive sampling to determine volume weights is unlikely to yield reliable figures.

An alternative method for estimating volume weights was sought. Various methods using particle size distributions as predictors of volume weight were unsuccessful, partially because of the coarse nature of the sediments in the sample. The best method involves a regression analysis of volume weight versus percentage of organic matter, which yields an r-squared value of 0.95 and a standard error of estimate due to regression of 7.3 pounds per cubic foot. Recommendations for future sampling include taking auger core samples on a grid pattern from each reservoir, evaluating organic matter content of the samples, and estimating volume weights from the regression relation. This method is expected to yield more accurate volume weight data, with less effort, than would be obtained by intensive sampling for direct measurements of volume weight.

The author points out that organic sediments may constitute a more significant percentage of total sediment volume weights on forested watersheds than had previously been thought. An average value of 5.1 percent of total sediment weight for the samples in the study is attributed to organic content, and individual sample values are sometimes much higher. Because levels of organic sediments are important determinants of water quality, they should be taken into account when planning land use.

Megahan, W. F. 1974. Erosion over time on severely disturbed granitic soils: a model. Res. Pap. INT-156. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.

A negative exponential equation containing three factors is derived to describe time trends in surface erosion on severely disturbed soils. Data from four studies of surface erosion on roads constructed from granitic materials found in the Idaho batholith (including 1961 to 1967 sediment dam data measuring erosion from road fill, cut, and tread areas in the Deep Creek watershed) are used to develop the equations. The regression of the Deep Creek data (which has an r-squared value of 0.98 and a standard error of 502 tons per square mile) indicates a long-term post-disturbance equilibrium erosion rate of 3.5 tons per square mile per day, which matches the value obtained from the Silver Creek road data. The author uses rainfall-intensity data to illustrate that variations in erosion forces, as indexed by rainfall kinetic energy times the maximum 30-minute rainfall intensity (the erodibility index), are not the cause of the time trend in surface erosion. In addition, although vegetative growth can be an important factor in reducing accelerated erosion, it did not cause the rapid erosion decreases found in the cases studied. The evidence suggests that surface "armoring" was the dominant factor causing the time trends in surface erosion. The exponential relationship between time and erosion indicates the need for immediate erosion control measures on newly constructed roads to minimize soil losses during the critical period of the first year or two following construction. (Adapted from author's abstract.)

Megahan, Walter F. 1975. Sedimentation in relation to logging activities in the mountains of central Idaho. In: Present and prospective technology for predicting sediment yields and sources: Proceedings of the sediment-yield workshop; 1972 November 28-30; Oxford, MS.

Publ. ARS-S-40. Oxford, MS: U.S. Department of Agriculture, Agricultural Research Service, Sedimentation Laboratory: 74-82.

In the Idaho batholith, early logging activities were concentrated on lands with low erosion hazard. By the mid-1950's, most of these areas of the batholith had been harvested, and loggers moved into areas with higher erosion potential. In 1960, the Forest Service began research on the effects of logging in these areas. These studies fell into three categories: assessment of sedimentation on undisturbed watersheds, quantification of sedimentation due to logging and logging road construction, and evaluation of downstream effects of accelerated sedimentation.

Surveys of sediment detention reservoirs on 14 perennial watersheds (seven in the Zena Creek Study Area and seven in the Silver Creek Study Area) yield reliable estimates of watershed sedimentation due to the dominance of coarse-textured materials that are transported as bedload. In the undisturbed state, average annual sediment yields for these watersheds as measured between 1960 and 1972 range from 4.5 to 26.9 cubic yards per square mile per year. Considerable variation occurs from year to year for each watershed, and the watersheds with the highest sediment yields show the greatest variation. Sediment frequency curves are developed using log Pearson type III frequency analyses for some of the watersheds (including Tailholt Main and Circle End Creeks) having records for 7 years or more.

Included are studies of volume weights of the detention reservoir sediments (see Megahan 1972 for details of this study) and studies on the Deep Creek logging and logging road sediment (see Megahan and Kidd 1972a, 1972b).

Data collected between 1966 and 1971 on the size of surface materials on the bed of the South Fork of the Salmon River show definite time trends following the cessation of logging in 1966. At the Krassel spawning area, sands decrease at a rate of 5.9 percent per year; gravels increase at a rate of 6.2 percent per year. This results in more favorable spawning conditions for the anadromous fish populations. These trends are apparent at the other study sites and are confirmed by studies of channel cross-sections and inspection of aerial photos. The trends are attributed to lowered erosion rates on sediment source areas, lack of time for mass erosion hazards to rebuild following the extreme events of 1965, favorable flow conditions for sediment transport, and lack of extreme climatic events during the recovery period. These conditions allow sediment transport through the system to proceed at a more rapid rate than sediment deposits into the system.

Megahan, Walter F.; Clayton, James L. 1986. Saturated hydraulic conductivities of granitic materials of the Idaho Batholith. Journal of Hydrology. 84: 167-180.

Saturated hydraulic conductivity (Ksat) of granitic bedrock in the Idaho batholith was determined using a borehole pressure testing technique. Tests, conducted at approximately 1.6-m depth increments, range from about 1.6 m to an average maximum depth of 7.8 m. A total of 58 valid tests were obtained in nine holes at five sites (including one at Lick Creek) in a 145-km long transect line running north-south in the southwest quarter of the batholith. Sites represent a wide range in rock fracturing and weathering properties. Seismograph profiles were also run at each test hole. A conditional probability analysis shows that Ksat values are lognormally distributed with a lower bound at zero. Values for Ksat are unrelated to depth, rock matrix porosity, seismic velocity, or rock fracture density. However, Ksat does vary with rock weathering characteristics. Conductivity is lowest in unweathered rock, probably because of restricted fracture apertures. The second least weathered rock class has the highest average Ksat. There is a general decrease in Ksat with increased weathering through the remaining five weathering classes even though rock porosity and fracture density increase with rock weathering. The authors believe that this inverse trend in Ksat with increased weathering is the result of progressively increasing clay formation and mineral expansion that restricts flow in both fractures and the rock matrix. Ksat for bedrock averages an order of magnitude less than Ksat for soil cores, and two orders of magnitude less than Ksat obtained by tracer tests during subsurface flow, making shallow subsurface flow a major hydrologic process at many locations on steep mountain slopes. (Adapted from authors' abstract.)

Megahan, Walter F.; Kidd, Walter J., Jr. 1972a. Effect of logging roads on sediment production rates in the Idaho Batholith. Res. Pap. INT-123. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 14 p.

Sediment production is monitored for 6 years following jammer road construction in three ephemeral drainages near the head of Deep Creek in the Zena Creek logging study area. The watersheds cover 10 acres, and the roads in the drainages amount to 0.36 miles. Sediment dam data were collected twice each year from November 1960 until September 1967. The road was constructed in October 1961. Following logging in October and November 1962, water bars were installed and the road was seeded with grass.

In the 6 years following construction, surface erosion produced 2,413.5 cubic feet of sediment, and one mass erosion event produced 6,030 cubic feet of sediment, for a total of 8,443.5 cubic feet. When compared to sediment production on nearby undisturbed watersheds (measured as 0.07 tons per square mile per day), this translates to an increased sediment production of 770 times the undisturbed rate. Surface erosion increased production 220 times; mass erosion, 550 times. A definite time trend is apparent: 84 percent of the total sediment is produced within the first year following construction, and 93 percent within the first 2 years. In the first measurement period following construction (238 days), the sediment production rate is 1,560 times the undisturbed rate. Rates decrease rapidly in subsequent measurement periods, and then fluctuate between 0 and 100 times the undisturbed rate.

The rates are unlikely to ever return permanently to the undisturbed level because of the rapid disintegration of bedrock on the cut and tread portions of the road prism. However, the authors suggest that sediment production rates could be minimized by limiting mileages of roads built; using care in road location, design, construction, and

maintenance; applying fill stabilization treatments, not limited to seeding, as soon as possible after construction (most of the initial sediment production was from fills); and providing barriers (such as logs and debris) to limit downslope movement of sediment.

Megahan, W. F.; Kidd, W. J., Jr. 1972b. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. Journal of Forestry. 70(3): 136-141.

Erosion and sediment production processes as affected by two logging systems (jammer and skyline) and by road construction are evaluated near the head of Deep Creek in the Zena Creek logging study area. The jammer unit is 21.5 acres; the skyline unit, 22.4 acres. Both were logged in October and November 1962. Study methods include the use of sediment dams in ephemeral channels and 1/100-acre erosion plots.

Erosion plot data, collected between September 1961 and September 1967, isolate the onsite effects of the logging activities, excluding road construction. These data show no significant difference in the rates of erosion due to the two skidding techniques. The erosion rates related to skyline logging might be higher than expected due to use on straight to convex (rather than concave) slopes and the fact that the equipment had been used for downhill (rather than uphill) skidding.

The sediment dam data enable the researchers to evaluate separately the effects of road construction and logging on sediment production. Measurements of erosion rates in the undisturbed condition made in nearby study watersheds yield a value of 0.07 tons per square mile per day. Based on 4.8 years of postlogging sediment dam data, logging alone increases this value by 0.04 tons per square mile per day, or by 0.6 times. Based on 1.35 years of prelogging data and 4.8 years of postlogging data, the increases in sediment production due to roads are 56.2 and 51.0 tons per square mile (of roads) per day, respectively, or an average increase of 750 times the natural erosion rate.

The greatest advantage of the skyline system in terms of erosion reduction is in the less extensive road system required to support it. The use of other logging systems using even fewer roads is judged desirable, and the authors recommend that in the future road location, construction, stabilization, and maintenance be done with greater care.

Megahan, Walter F.; Platts, William S.; Kulesza, Bert. 1980. Riverbed improves over time: South Fork Salmon. In: Proceedings, symposium on watershed management; 1980 July 21-23; Boise, ID. New York: American Society of Civil Engineers: 380-395. Vol. 1 of 2 vol.

The South Fork of the Salmon River historically supported one of Idaho's largest chinook salmon runs as well as a large run of steelhead trout. From 1950 to 1965, considerable logging and attendant road construction activities took place in the South Fork watershed. A combination of highly erodible soils, steep slopes, widespread soil disturbances from logging and road construction, and some large storm events in 1955, 1962, 1964, and 1965 caused severe sedimentation in the river, filling many of the prime salmon spawning and rearing areas with sand. The Forest Service responded to the problem by developing a restoration program that included a moratorium on all road construction and logging activities, and a variety of watershed rehabilitation practices. River responses were monitored by photographic documentation, surveys of channel cross sections to document changes in bottom elevation, a series of transects to evaluate the particle-size distribution on the surface of the riverbed in both chinook salmon spawning and rearing areas, and core samples of the channel bottom to determine changes in the particle-size distribution of the channel substrate in spawning areas. Data collected from 1966 to 1979 show statistically significant decreases in bottom elevation and increases in the particle size of bottom materials, indicating an improvement in fish habitat conditions. Improvement is dramatic enough to provide the basis for a cautious reentry into the South Fork watershed for timber harvest purposes beginning in 1978. A second paper (Cole and Megahan 1980) describes how this is to be accomplished. (Adapted from authors' abstract.)

Mickelson, Hal L.; Kulesza, Norbert C.; Stephenson, Clifford R.; Platts, William S. 1973. Review and analysis of the South Fork Salmon River Rehabilitation Program. Boise and McCall, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 357 p.

The South Fork Salmon River aquatic environment steadily degraded from 1952 to 1965 because of large (unnatural) accelerated sediment accumulations in the channel system. Investigation in 1966 and 1967 revealed that most of the accelerated sediment originated from roads, skid trails, and "logging only" areas. Except as required to complete existing timber sale contract commitments, logging and road construction activities ceased in 1965. Based upon findings of the South Fork Salmon River Special Survey made from 1966 to 1967 (Arnold and Lundeen 1968), a watershed rehabilitation program was proposed to reduce the volume of accumulated sediments in the river by means of instream sediment traps, and also to reduce the rate of accelerated sediment production by closing and stabilizing logging roads, relocating certain sections of the South Fork Salmon River Road, and stabilizing main roads, skid roads, "logging only" areas, and other lesser sediment-producing areas. Funding for detailed planning and for rehabilitation work was not obtained until 1971. This reanalysis was then made of the problems.

From 1965 to 1971, at least 2 years of favorably high river energies had reduced the volume of sediments in the river by an estimated 40 percent. Natural stabilization of accelerated sediment-source areas had reduced sediment production by an estimated 45 percent. The river will likely continue to flush the excessive sediment accumulations and reach near-natural conditions within the next decade or two without further treatment, assuming no further land disturbance occurs. Natural stabilization processes on sediment source areas can be accelerated by treatment. By reducing the rate of sediment inputs to the river, excessive sediment accumulations may be eliminated allowing the stream to return to natural conditions. Most sediment reduction achieved by 1971 through natural processes

resulted from the reduction of surface erosion. Before treatment, the potential for mass erosion or mass failure was similar to 1967. The treatment program that began in 1971 should further reduce both mass erosion and surface erosion potential. Overall, natural stabilization plus treatment will reduce sedimentation rates from accelerated sediment source areas by an estimated 80 percent from 1967 estimated levels. This will provide a comfortable margin of safety to absorb unusually heavy climatic impacts without damage to the river system or the aquatic environment. It will also give the land manager greater leeway in choosing alternatives for management programs in the watershed. The recommended treatment program includes stabilization of logging roads, main roads, the Poverty Burn, and the livestock driveway. It does not include sediment traps, road relocation projects, or treatment of skid roads or "logging only" areas. Skid roads and "logging only" areas have stabilized substantially by natural means since standard treatment for erosion control following logging.

Newberry, Donald D.; Corley, Donald R. 1984. Fishery habitat survey of the South Fork Salmon River—1983. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise and Payette National Forests. 71 p.

For the fifth in a series of reports, the physical habitat, as related to fishery requirements, was monitored in the South Fork Salmon River in 1983. Composition of fine sediments in upper spawning areas fluctuates over the period, without exhibiting any trends, either positively or negatively. However, lower regions of the river improve with respect to fine sediment volume. For example, in 1983, a 4.3 percent decrease in fine sediments occurred in the Poverty Flats area.

Note: The first four publications in this series are Corley (1976), Corley and Burmeister (1978, 1980), and Corley and Newberry (1981).

Noble, E. L.; Lundeen, L. J. 1970. Analysis of rehabilitation treatment alternatives for sediment control. In: Proceedings of the symposium on forest land uses and stream environment; 1970 October 19-21; Corvallis, OR. Corvallis, OR: Oregon State University: 86-96.

This study set out to determine the best (most cost-effective) method to reduce sediment production resulting from land uses in the South Fork drainage. Researchers use computer analysis of 190 possible treatment alternatives to select superior treatments. To reduce the accelerated sedimentation rate of 63,000 cubic yards annually, treatments costing $5 million would have to be implemented. Debris basins prove to be the most effective and economical treatment available.

Ohlander, Coryell Archer. 1964. Effects of rehabilitation treatments on the sediment production of granitic road materials. Fort Collins, CO: Colorado State University. 78 p. M.S. thesis.

Six surface treatments (chipped slash, one layer paper netting, three layers paper netting, asphalt-straw, surface holes, and control) are evaluated for surface erosion control and revegetation enhancement on the fillslope of a new secondary logging road in the Zena Creek study area. The study section of the road is insloped and located on a steep south exposure at 4,500 feet elevation. The road was constructed in June 1962. Study plots were installed and initial soil properties evaluated in August 1962. Treatments (including seeding and fertilization of all plots except the controls) were applied in September 1962. Measurements of sediment and vegetation production as well as of posttreatment soil properties were made in the spring and summer (April through July) of 1963. Climatic analyses show that the study period provides a good indication of the efficiency of the treatments for reducing erosion due to raindrop splash, but provides no test of performance under conditions of surface runoff and little indication of treatment effects on revegetation under conditions of soil moisture deficiency.

Prior to vegetative growth (the treatment stage), the asphalt-straw treatment was most effective in reducing sediment production, and the treatment consisting of one layer of paper netting was the second most effective (with respective sediment production of 242 and 302 pounds per acre). The other methods performed poorly (with sediment production exceeding 10,000 pounds per acre), although the value for the treatment with three layers of paper netting may be artificially high due to the data from one plot. After vegetative growth began, but while the treatments were still playing a major role in erosion control, the same two treatments (but in the opposite order) exhibited the best performances in terms of limiting sediment production (with values of 128 and 138 pounds per acre). After the treatments had become of secondary importance in erosion control, evaluation was made of the production of vegetation on each plot. The same treatments were again judged best. The treatment with one layer of paper netting produced 2,039 pounds of vegetation per acre, while the asphalt-straw treatment had a corresponding value of 1,599 pounds per acre.

The following trends are observed in the soil properties following most of the treatments (although not significantly different between treatments): percentages of silt and clay increase, moisture retention increases, organic matter increases, nitrogen increases in the upper soil levels, cation exchange capacity increases, and upper soil layers become more acidic. Bulk densities, structure, and textural classes do not appear to change in the first year following treatment. There is some variation in soil properties between ridges and swales.

None of the treatments provide significant reductions in slope susceptibility to erosion, but the treatment with one layer of paper netting exhibited the best performance under the somewhat unusual climatic conditions prevailing during the year of the study.

Olson, O. C.; Arnold, J. F. 1960. Soils of the Zena Creek logging study, Payette National Forest. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 29 p. plus maps.

Sixteen soil mapping units are described in the Zena Creek logging study area. Ten of these are composed of single soil taxonomic units; six are composed of two soil taxonomic units. For each of the mapping units, a nontechnical and a more detailed technical description of the soil are presented and erosion hazards assessed. Representative pictures and soil profiles are included for several of

the units. All of the soils are acidic sandy soils derived from granitic parent materials and have weakly developed profiles. Water movement into and through most of the soils is rapid. The most widespread units are those numbered 2, 8, and 12. These are all grayish sandy soils but differ in average soil depth (8 to 16, 20 to 40, and >40 inches, respectively), average slope gradient (60 to 75, 45 to 60, and <40 percent), water storage (very low, moderate, and high), erodibility (high, moderate, and moderate), and suitability for timber production (low, moderately low, and high).

Ortmann, David W. 1963. Determination of the timing and distribution of adult salmon and steelhead runs. Idaho Fish and Game. 13(154): 92-97.

A temporary counting weir was operated in the South Fork Salmon River during the 1963 chinook run to determine the feasibility of weirs to enumerate anadromous fisheries. Several weir designs were tested and a satisfactory system was selected. The author recommends full monitoring using the preferred weir during the 1964 run.

Ortmann, David W. 1964. Salmon and steelhead harvest and escapement studies, South Fork of the Salmon River. Idaho Fish and Game. 17(1): 1-18.

During the 1964 fishing season, anglers caught 737 steelhead and 1,709 chinook salmon from the South Fork Salmon River drainage. Weir counts indicate 2,895 chinook entered the river. Of the run, 36 percent was harvested, leaving a spawning escapement of about 1,800 fish.

Ortmann, David W. 1965. Salmon and steelhead harvest and escapement studies, South Fork of the Salmon River. Idaho Fish and Game. 17(4): 1-10.

Due to a sport-fishing closure, no chinook harvest estimates were made in 1965. Weir counts indicate a run of 2,000 chinook adults. Because of high water conditions, less than 100 steelhead were harvested in 1965 on the South Fork Salmon River.

Ortmann, David; Richards, Monte. 1964. Chinook salmon and steelhead sport fisheries in the South and Middle Fork drainages of the Salmon River 1961-1962. Idaho Fish and Game. 14(175): 1-29.

This study represents a continuation and expansion (includes chinook data) of Richards' (1962) initial studies of South Fork Salmon River steelhead runs. Three checking stations collected data on number of angler days, number of fish caught, and stream areas fished. Data are recorded separately for the lower and upper South Fork Salmon, East Fork, Johnson Creek, Lake Creek, and the Secesh River. A total of 4,933 anglers spent 9,879 days harvesting 1,745 chinook. Anglers averaged 0.35 chinook per trip. Calculated harvest is 31.8, 29.7, and 26.1 percent of the South Fork, Johnson Creek, and Secesh River runs, respectively.

Platts, William. 1967. The use of a sediment trap in containing moving bedload materials. Unpublished report on file at: Idaho Department of Fish and Game, Boise, ID. 1 p.

During the summer of 1966, accumulated instream sediment was dredged from the Krassel Hole on the South Fork Salmon River in an attempt to form a barrier to downstream-moving sediment. About 16,000 cubic yards of sediment material were removed at a cost of $20,000. High costs make use of this method for stream rehabilitation questionable.

Platts, William S. 1968. South Fork Salmon River, Idaho, aquatic habitat survey with evaluation of sediment accruement, movement, and damages. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 135 p.

This report, a companion to the South Fork Salmon Special Survey (Arnold and Lundeen 1968), specifically documents the effect of sedimentation on aquatic habitat and on the fishery resource. Data are from 325 randomly located stream transects and 90 transects on the spawning areas, and from core samples of the streambed. Between 1962 and 1967 sediment increased in the upper 25 miles of the stream by 100 percent. The 1967 studies show a very high sediment content with fine sediments composing 55 percent of the streambed materials on the spawning beds and 50 percent of the streambed surface from its head to the confluence with the Secesh River. This sediment seriously damaged the aquatic habitat by lowering the permeability of the materials in the spawning beds. It also eliminated rearing and overwintering areas, reduced food supplies, and formed blankets of impenetrable sediment over salmonid production areas. Sediment transport was evident during all periods of the year due to the filling of deep pools and a lack of sediment trapping areas. This resulted in movement of sediment onto new redds immediately following the spawning and incubation periods.

At the Krassel Hole, 16,000 cubic yards of sediment were removed from the channel in September 1966. By the following August the hole was filled again. Over 4,000 cubic yards were trapped before high water in May 1967. During that period, additional sediment passed through the hole and continued downstream. This is estimated at 50,000 cubic yards, less that which was trapped. (Annotation from Skabelund 1970.)

A followup progress report is listed under Platts 1972.

Platts, William S. 1969a. The effects of sediment reduction on the fishery resource of the South Fork Salmon River. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 4 p. plus 2 tables.

This report, a companion to the economic evaluation report (Platts 1969c), appraises the effects of the proposed restoration program on the fisheries resource. Accelerated sediment has severely impacted the production, rearing, and fishing environments on various sections of the South Fork. Most of this damage has resulted from deposition and scouring of sediments under 9 mm in size. All three of the environments need improvements to restore the fishery. The author concludes that it would be senseless to attempt to rehabilitate one environment without the others, as each is a limiting factor. Restoration for the Stolle Meadows area would show immediate fishery benefits. Debris basins should be planned to restore rearing and spawning areas simultaneously.

Platts, William S. 1969b. Lost Creek drainage aquatic habitat as related to past, present, and proposed logging—Payette National Forest. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 52 p.

Portions of the Lost Creek watershed had been extensively logged into the late 1960's. One type of logging, clearcutting, then in operation and programmed for future use in the drainage has been well documented in the literature for its potential destructiveness to the aquatic habitat. Logging operations of the type and magnitude programmed for the study area (as of October 1968) could possibly have produced detrimental effects to the aquatic habitat. Direct evidence was lacking, so this report presents indirect evidence supporting this thinking. The author reviews past, present, and predicted future aquatic habitat conditions. (Adapted from author's abstract.)

Platts, William S. 1969c. South Fork Salmon River fishery impact and rehabilitation evaluation. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, UT. 10 p.

Of the various methods of economic evaluation made on the fishery habitat of the South Fork drainage, the author dicusses which is the most accurate. He says the resident fishery in the late 1960's is worth about $22,650 annually. The anadromous fishery has a value to countries and States other than Idaho.

The value of the anadromous fishery is estimated at $56,650, compared to $432,150 in the late 1950's. This reduction has come about largely as a result of downstream dams and deterioration of aquatic habitat; the former is the most important of the two factors. Habitat deterioration is still an important factor.

The author discusses hatchery production of both resident and anadromous fish. Initiation of a hatchery program along with restoration of the river to optimum conditions would produce a fishery value estimated at $3,365,100 annually. The author considers estimates in this report to be conservative. They do not include any estimate of the intrinsic values of a fishery. Information from this report is in the May 20, 1969, proposal to the Chief for restoration of the South Fork. (Annotation from Skabelund 1970.)

Platts, William S. 1970. The effects of logging and road construction on the aquatic habitat of the South Fork Salmon River, Idaho. In: Western proceedings - 50th annual conference of the Western Association of State Game and Fish Commissioners; 1970 July 13-16; Victoria, BC. Victoria, BC: Western Association of State Game and Fish Commissioners: 182-185.

A major tributary to the Salmon River, the South Fork drainage is characterized by steep mountainous terrain and is composed almost entirely of granitic materials in various stages of decomposition. The South Fork has historically contained Idaho's largest salmon run composed entirely of summer chinook, a species in danger in the Columbia River system. Historically, this run made up about 20 percent of Idaho's total salmon run and 30 percent of Idaho's harvest. It played an important part in both the downriver commercial and the upriver sport fisheries. The drainage was not always plagued by fine sediments. Prior to 1952, it was in good aquatic habitat condition. This was demonstrated both by field inspection and size of anadromous salmonid runs. From 1962 through 1967, the streambed surface sediment content (9.51 mm and below) increased 100 percent in the upper South Fork (25 miles). From the author's visual observation, as well as streambed surface and depth sampling, it appears this has occurred throughout the South Fork proper. The steelhead trout, salmon, and resident game fish populations have steadily declined from the levels of previous years, resulting in complete or partial closures on segments of the fishery resources. The decline of the summer chinook salmon run into the South Fork Salmon River has caused great concern. (Adapted from author's abstract.)

Platts, William S. 1972. Sediment in a salmon steelhead environment. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; Progress Report II. 106 p.

This is a follow-up study to Platts (1968). The South Fork Salmon River aquatic environment has steadily degraded in quality, due to accelerated sedimentation from disturbed lands. Most of the degradation occurred between 1962 and 1965. Prior to 1952, the drainage was in good aquatic environmental condition. From 1952 to 1965, the South Fork was incapable of discharging the accrued bedload sediment as fast as it was being recruited. This period corresponded with the increase in logging and road construction activities. The result of these activities caused accrued bedload sediment to overwhelm and destroy much of the drainage's aquatic environment and that of some tributaries. From 1966 to 1971, an equilibrium between sediment import and export within the watershed and within the channel existed. During this period, logging and road construction were suspended because of a logging moratorium. Based on related studies, the accumulation of fines has degraded the South Fork's aquatic environment by lowering the permeability of spawning areas and covering the food-producing riffle areas. Fine sediment also eliminated rearing and overwintering areas and formed blankets of sediment on the surface and within the salmonid spawning areas. (Adapted from author's abstract.)

Platts, William S. 1974a. Chinook salmon runs, fish standing crop and species composition in South Fork Salmon River, Idaho. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; Progress Report 5. 48 p.

This report summarizes information regarding the fish populations of the South Fork Salmon River, including both resident and anadromous populations in 38 upper tributaries. Chinook salmon and steelhead trout numbers declined after 1958, as a result of downriver passage problems associated with the development of hydroelectric power in the Columbia River. Resident fisheries also declined after 1964, although this decline is attributed to the influx of massive amounts of fine sediment within the South Fork Salmon River watershed.

Chinook salmon spawn primarily in the main stem of the South Fork, while steelhead prefer tributary streams.

Survey results indicate that rainbow trout (including steelhead) dominate (50 percent) numbers of fish found in the tributaries. Chinook salmon are second in importance (25 percent) and are found primarily in the lower tributaries. Cutthroat trout, brook trout, bull trout, whitefish, and sculpin make up the remainder of species observed.

Analysis of fish populations by landform reveals the following trends: (1) the depositional and fluvial landforms support almost all of the fish, (2) no fish are found in cryoplanated landforms, (3) rainbow trout are the only species found in strongly glaciated landforms, (4) chinook salmon are found mainly in alluvial geomorphic type landforms, and (5) 80 percent of the fish are collected between 3,600 and 5,200 feet elevation.

Platts, William S. 1974b. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem classification. Ogden, UT: U.S. Department of Agriculture, Forest Service, Surface Environment and Mining Program, Intermountain Region. 198 p.

Investigations are conducted from July 1970 through September 1972 on 38 streams in the upper South Fork Salmon River. The streams have distinguishing features resulting from the influences of geomorphic processes. Multivariate geomorphic processes generally influence stream condition. Fish populations, in turn, are controlled by aquatic structural characteristics such as depth, width, and elevation of stream channel.

Platts, William S. 1974c. Stream channel sediment conditions in the South Fork Salmon River, Idaho. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; Progress Report 4. 38 p.

Channel substrate composition in the South Fork Salmon River is monitored at seven stations during 1973. Most sites exhibit stable or decreasing trends in percentage of fine sediments, while the percentage of gravel increases. Rubble and boulder composition remains fairly stable, probably because of the depositional characteristics of the area.

Platts, William S. 1979. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries. 4(2): 5-9.

This study examines the relation between stream order, fish populations, and geomorphic variables in the South Fork Salmon River. As stream order increases, width and depth increase while percentage of channel containing rubble and gravel and channel gradients decrease. With increasing order, the numbers of chinook salmon, rainbow trout, and sculpin increase, while numbers of bull and cutthroat trout decrease. Fish populations are greatest in stream order 4. Management implications include using stream order as a guide for classification and analysis of fishery populations.

Platts, William S. 1981. Stream inventory garbage in—reliable analysis out: only in fairy tales. In: Armantrout, N. B., ed. Acquisition and utilization of aquatic habitat inventory information: Proceedings of a symposium; 1981 October 28-30; Portland, OR. Portland, OR: Western Division, American Fisheries Society: 75-84.

The accuracy or precision of a number of commonly used stream survey measures is evaluated in 13 study sites including the South Fork Salmon River.

Platts, William S.; Martin, Susan B. 1980. Return of the South Fork Salmon. Idaho Wildlife. 2(4): 3-9.

A combination of poor land management and climatological events almost destroyed one of Idaho's most beautiful and productive rivers. But the lesson, bitter as it was, is learned, and the river is making a comeback. The battle isn't over. We have to keep on assisting this river to recovery. (Adapted from article's introduction.)

Platts, William S.; Megahan, Walter F. 1975. Time trends in channel sediment composition in salmon and steelhead spawning areas: South Fork Salmon River, Idaho. On file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID. 21 p.

The South Fork Salmon River is an important chinook salmon and steelhead trout fishery in the mountains of central Idaho. Because of increased logging, road construction, and severe floods after 1950, excessive sediment, especially fines, was deposited in the river channel, seriously damaging the major spawning areas by 1966. A study using a network of closely spaced stream channel cross sections evaluates the riverbed surface materials by size in four major spawning areas in the upper half of the river. The size composition of materials favorable for spawning improved greatly from 1966 to 1974; a large decrease in fines was accompanied by a large increase in gravels and a lesser increase in rubble. The change in spawning materials results from a reversal of the previous high rate of sediment flow into the channel system compared to sediment flow out of the system. The reductions in watershed erosion and sediment entry into the river result from (1) a moratorium on logging and road construction activities on the watershed, (2) natural watershed stabilization processes, and (3) a watershed rehabilitation program. This study demonstrates that logging and road construction on high-erosion-hazard lands such as those in the South Fork Salmon River watershed must be carefully planned and programmed over both time and space to avoid degradation of salmonid spawning areas.

Platts, William S.; Partridge, Fred E. 1978. Rearing of chinook salmon in tributaries of the South Fork Salmon River, Idaho. Res. Pap. INT-205. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 11 p.

Fish populations in 23 tributaries of the South Fork Salmon River were sampled in 1971, 1972, and 1974. Juvenile chinook salmon were found in one secondary and 11 primary tributaries. The first 400-m reach of tributary stream adjacent to the South Fork was the most important area for rearing, and supported 58 percent of the total tributary chinook salmon population. Only three tributaries have chinook salmon more than 1.6 km from the river. The tributary chinook salmon density ranges from 0.01 to $0.38/m^2$ and averages $0.06/m^2$ for all streams.

Chinook salmon are rearing with rainbow trout and sculpin over most of their tributary range and occasionally with brook trout, Dolly Varden, mountain whitefish, mountain suckers, and dace. Cutthroat trout and chinook

salmon are not found together. Chinook salmon prefer the larger, lower gradient, grassy-banked streams that have deep pools. Chinook salmon are found in the fluvial and depositional landtype associations, but mainly in the alluvial and alluvial fan landtypes. (Adapted from authors' research summary.)

Platts, William S.; Partridge, Fred E. 1983. Inventory of salmon, steelhead trout, and bull trout: South Fork Salmon River, Idaho. Res. Note INT-324. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 9 p.

Aquatic habitats and their respective fish populations were studied in the South Fork Salmon River during the summer of 1977. From the Warm Lake Bridge to the headwaters, the channel consists of 74 percent riffle and 26 percent pool, with surface substrate of 21 percent boulder, 40 percent rubble, 24 percent gravel, and 15 percent fine sediment. Below the Warm Lake bridge to the confluence of the Secesh River, the channel consists of 55 percent riffle and 45 percent pool, with surface substrate of 32 percent boulder, 35 percent rubble, 16 percent gravel, and 17 percent fine sediment. Juvenile chinook salmon and rainbow-steelhead trout are found throughout the river, except in the upper 5 miles, where only bull trout are found. The river reach in the Stolle Meadows contains the highest densities of fish, with juvenile chinook salmon and sculpin the most numerous. Chinook salmon and rainbow steelhead trout densities are lower than reported in most other Idaho streams having anadromous fishes. Of the habitat attributes measured, only stream width shows any correlation with fish populations. As stream width increases in the river reach above the Warm Lake bridge, bull trout numbers decrease. (Adapted from authors' abstract.)

Platts, William S.; Penton, Vance E. 1980. A new freezing technique for sampling salmonid redds. Res. Pap. INT-248. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p.

A new multiprobe freeze method for determining salmonid redd sediment particle size distribution will collect salmonid eggs and alevins in the redd at any stage of development, any air or water temperature, any stream depth, and will determine their horizontal and vertical location. This method will improve our understanding of embryo and alevin survival rates and causes of their mortality.

The freeze-core method differs from the past freeze methods that expand CO_2 liquid to atmospheric pressure. This method expands CO_2 to a pressure of 78 psi, which provides a higher heat transfer, cooling efficiency, and fewer clogging problems. One field test shows the ratio of CO_2 consumed to redd materials lifted as 0.34 lb CO_2 per 1 lb of redd material. The paper contains description of the methodology with a listing of parts, materials, and suppliers. (Adapted from authors' research summary.)

Platts, William S.; Shirazi, Mostafa A.; Lewis, Donald H. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. EPA-600/3-79-043. Corvallis, OR: U.S. Environmental Protection Agency, Environmental Research Laboratory. 33 p.

Researchers determine the size composition of substrates used by chinook salmon for spawning in the South Fork Salmon River, the main Salmon River, and tributaries of the Middle Fork Salmon River. Substrates used by resident trout are analyzed for streams in the Boise and Payette River drainages. These analyses are made spatially to determine particle sizes preferred by spawning salmon, yearly differences in sizes used by these salmon, the size differences used by spring and summer chinook salmon, and differences between channel sediments used by chinook salmon for spawning and those substrates occupied by trout.

The authors present the use of the geometric mean particle diameter method as a companion measurement to "percent fines" for a more complete analysis of sediments used for spawning. The geometric mean particle diameter is more adaptive to statistical analysis than the more common method of using percent fines. The geometric mean diameter of the sediment particle size distribution is used for analyzing channel sediments. The relationship is established between the geometric mean particle diameter and percent fines substrate permeability, and substrate porosity. The strongest correlation between the two methods of analysis, percent fines and geometric mean diameter, is for fine sediments below 0.88 inches in particle size.

Chinook salmon select sediments for spawning that are mainly between 0.28 and 0.79 inches in geometric mean particle diameter, regardless of stream selected. This is a narrow range considering that the mean particle diameters for streambed sediments available for chinook salmon to spawn in vary from less than 0.02 inches to well over 3.94 inches. The composition of spawning sediments selected by chinook salmon each year between 1966 and 1976 was quite uniform. Sediments used in spawning in the South Fork Salmon River decrease in particle size in a downstream direction. Geometric mean diameters 35 miles below the headwaters averaged 0.35 inches; particles 10 miles below the headwaters averaged 0.58 inches. (Adapted from authors' abstract.)

Primbs, Edward R. J.; Platts, William S. 1976. The colonization of the South Fork of the Salmon River by the Columbia sculpin (*Cottus hubbsi*). Journal of the Idaho Academy of Science. 12(1): 47-49.

During September 1975, fish populations were sampled at two sites on the South Fork Salmon River. At one site only bull trout (*Salvelinus confluentus*) were collected. At the other site rainbow/steelhead trout (*Salmo gairdneri*), chinook salmon (*Oncorhynchus tshawytscha*), and the Columbia sculpin (*Cottus hubbsi*) were found. The South Fork is one of Idaho's few remaining spawning and nursery grounds for chinook salmon and steelhead trout. Studies show that the sculpin is a predator of salmonid fry and a serious competitor with salmonid fingerlings for stream territory. The senior author suggests that the presence of the Columbia sculpin in the South Fork could be detrimental to Idaho's anadromous fish.

Richards, Monte. 1960. The chinook salmon sport fishery of the South Fork Salmon River drainage. Idaho Fish and Game. 9(19): 1-36.

The author details harvest data on the major portion of the South Fork Salmon River chinook fishery for 1960.

Richards, Monte. 1962. The steelhead sport fishery of the South Fork Salmon River drainage, 1960-1961. Idaho Fish and Game. 9(121): 1-34.

At the time of this study, the relative size of this fishery was unknown. The study presents a realistic picture of the South Fork drainage (includes South Fork Salmon, East Fork South Fork Salmon, Johnson Creek, and Secesh River) steelhead fishery, through angler surveys and creek census.

Richards, Monte. 1963. Management of the chinook salmon fishery of the South Fork Salmon River drainage. Idaho Wildlife Review. July-August: 3-7.

This article describes management of the fishery from the standpoint of the Idaho Fish and Game Department and presents harvest, spawning success, and escapement data for 1958 to 1962. Significant increases in fishing pressure, due to ready accessibility from Boise, will lead to future limitations of harvest.

Skabelund, Paul H. 1970. [Untitled annotated bibliography concerning the South Fork Salmon River drainage.] Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest, McCall, ID. 12 p.

A chronological listing of reports dealing with "the resources and impacts of use thereon within the South Fork Salmon River Drainage" was prepared at the request of the Payette National Forest Supervisor. The author cites and annotates 19 reports written between 1960 and 1970.

South Fork Salmon River Monitoring Committee. 1979. Proceedings of the committee meeting; 1979 March 16; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 25 p.

This committee's assigned task was to coordinate research and monitoring efforts in the South Fork Salmon River. The committee's report covers the history of land use planning in the area since 1966 and time trends in sedimentation in response to development activities that began in the 1940's. In the 1960's, sedimentation increased beyond the ability of the river to discharge the additional loads. Suspension of land disturbances in 1966 and a rehabilitation program decreased new sediment deposits to the river and allowed removal of the accumulated sediments to begin. A graph of estimated sediment production from surface erosion on temporary logging roads between 1948 and 1974 shows the peak value occurring in 1961 (about 35,000 cubic yards) with secondary peaks in 1965 and 1958 (about 27,000 and 25,000 cubic yards, respectively), and a consistent decrease between 1965 and 1974 (the 1974 value is about 5,000 cubic yards). The numbers of returning adult summer chinook salmon and steelhead trout entering the South Fork undergo a steady decline from 1962 to the formation of the committee.

Plans for future logging, road construction, and mining include associated monitoring efforts. Natural erosion and sedimentation processes should be monitored as well. A summary cites past and ongoing research studies of erosion, sedimentation, streamflow, soil stabilization, channel characteristics, and aquatic habitat. Discussion of the fisheries habitat monitoring of the South Fork by the Boise National Forest (see Corley 1976 and Corley and Burmeister 1978 for results) includes existing and planned stream monitoring programs and fisheries studies.

Streamflow records of the U.S. Geological Survey show that the flood of December 1964, which caused a great deal of damage in the South Fork, was not limited to the South Fork. Record flows occurred throughout many areas of Idaho and in other Western States. The recurrence interval is on the order of 100 to 200 years. This and similar floods caused extensive damage even in some undisturbed areas, so it is difficult to assess the relative contributions of natural and accelerated erosion.

South Fork Salmon River Monitoring Committee. 1980. Proceedings of the committee meeting; 1979 December 12; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 22 p.

At the time of the meeting, the only monitored activity that introduces any significant sediment into the South Fork is construction work at the hatchery satellite facility project during the summer of 1979. It results in temporary exceedances of the Idaho State turbidity standards, but work stoppages are not required. A few other isolated incidents produced impacts in excess of those predicted. In those cases, modifications and mitigations were effective in controlling downstream impacts. Monitoring of sedimentation from natural events and from past management activities is being done to separate these impacts from impacts of the new land-use activities.

Heavy metal analyses of samples from four locations on the South Fork in the Cascade Ranger District show no significant abnormalities. Water quality samples collected at three sites on the South Fork in the Payette National Forest exhibit no change in water quality between 1976 and 1979. Cross-section measurements indicate that large amounts of sediment have been removed from 1966 to 1971, with little change from 1972 to 1973. In 1979, one site had significant aggradation, but all others had degraded to some degree. Aerial photographs of the South Fork show flushing of sediment from 1965 to 1972.

The chinook salmon run on the South Fork in 1979 is the lowest on record, which may be due in part to the drought. However, studies show that survival is high in years following drought. The committee members believe that the number of returning adults, rather than the lack of suitable habitat, is the limiting factor at the time, but that the existing habitat has to be protected nonetheless. (See Corley and Burmeister [1980] for results of the 1979 habitat monitoring.) Studies indicate that immediately after spawning, the redds in the South Fork were in good shape. Some changes in the percentages of the various bottom material size classes had occurred since 1967 and were particularly pronounced from 1967 through 1972.

The committee members agree that the South Fork is in a stable or slightly improving condition (due to the tight

controls on land-use activities) and could withstand a severe climatic event without major damage.

South Fork Salmon River Monitoring Committee. 1981. Proceedings of the committee meeting; 1981 January 29; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 4 unnumbered pages plus appendixes.

Results of monitoring activities are as follows (some published data included elsewhere in this bibliography will not be covered here): Six reaches of the South Fork show an overall decrease in fines and an increase in gravel and rubble since monitoring began in 1966.

Analysis of data collected by the U.S. Geological Survey at its stream gauge near Krassel Ranger Station shows a decrease in average streambed elevation of 0.37 feet from 1968 to 1979, or an average yearly decrease of 0.03 feet.

A summer chinook trapping operation near Cabin Creek trapped 380 fish (194 adults and 186 jacks). Of the adults, 38 percent had tags, indicating that they were involved in a 1978 hatchery release with an apparent return rate of 0.1 percent. The number of tagged jacks (29 percent of those trapped) indicates a return rate of 0.04 percent from a 1979 release.

Water quality monitoring at three sites (on the Secesh, South Fork, and East Fork South Fork) within the Payette National Forest shows no major changes in water quality from 1979 to 1980. Monitoring of 24 cross-sections of the South Fork in the Boise and Payette National Forests shows little change between 1979 and 1980.

Monitoring for 2 years on the Habitat Improvement Timber Sale near Camp Creek (the first timber sale on the South Fork planning unit since the moratorium) shows no major erosion problems and good revegetation. The South Fork Road Rehabilitation Program, implemented in 1979, significantly reduced potential surface and mass erosion hazards. Road reconstruction for the Teapot Timber Sale was done with minimal sediment delivery. The only problems involve flushing of channel sediment deposits during culvert replacement. Climatic stresses in the South Fork watershed were light to moderate between 1978 and 1980, and no significant adverse impacts due to management activities are noted during that period.

Macroinvertebrate populations sampled in 1980 exhibit a good balance among trophic groups, which is indicative of good water quality and habitat conditions.

Core samples collected in 1980 from six spawning areas had values ranging from 22.3 to 34.5 percent fines.

Data are included for water quality, streamflow, sediment, turbidity, and temperature for three small streams in the Boise National Forest for calendar years 1976 through 1980. Monitoring of 26 sites believed most likely to contribute sediment along the Warm Lake - Landmark Road Reconstruction Project (reconstruction was done in 1979) reveals that 19 had significant acceleration of sedimentation and three had minor sedimentation. Most of the fine sediments observed in 1979 had been flushed out by 1980. Two sediment traps below roads in the Roaring Creek Timber Sale collected 100 and 12 cubic feet between 1979 and 1980, compared with 0.5 cubic feet at an above-road site. Sedimentation was also observed during channel evaluations. The Roaring Creek area had road reconstruction activities in 1979. Preproject monitoring of creeks in the Bad Bear Timber Sale reveals that two of 18 sites are undergoing significant degradation or aggradation, and four sites show minimal sedimentation.

Aggradation, degradation, and pesticide introductions to the South Fork due to cofferdam construction were observed during 1979 monitoring of the hatchery satellite facility. Only minor impacts are noted in preliminary analysis of data from the Bear Creek Timber Sale, logged in 1980. Analyses of data from nine cross-sections of the South Fork show that six have a gain in area (indicating degradation) and three have a loss in area (indicating aggradation), with an average change in area of +3.45 square feet (the time interval involved is not clear). Sediment structure monitoring in Curtis Creek drainage shows 15 cubic feet entrained and 7 cubic feet enroute, for the three below-road structures. Amounts are insignificant for the above-road structures. In Tyndall Creek, one below-road structure has 6 cubic feet entrained and 4 cubic feet enroute. One above-road structure and three other below-road structures have no significant sediment entrained or enroute. Water quality data are included in the report.

South Fork Salmon River Monitoring Committee. 1982. Proceedings of the committee meeting; 1982 April 2; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 4 p. plus appendixes.

Results of monitoring efforts are as follows (some data published in references included elsewhere in this bibliography will not be repeated here): Eight monitoring studies (four baseline and four project) conducted by the Boise National Forest in 1981 do not show significant acceleration of erosion or sedimentation, with the exception of the Roaring Creek Timber Sale, where rill and gully erosion from a road fill produced a small amount of sediment. This sediment was trapped behind a retaining structure in a tributary of the South Fork. The 1981 water year is one of low to moderate hydrometeorological stress in the South Fork.

Water quality monitoring by the Payette National Forest on the Secesh, South Fork, and East Fork of the South Fork in 1981 shows no major changes from previous years. Aggradation occurred between 1980 and 1981 on 10 of 16 measured cross-sections of the South Fork, while the other six degraded. All cross-sectional changes are less than a 5 percent difference in area from the previous year, with one possible exception. The report from the Krassel Ranger District indicates a lack of significant impacts in 1981 from land use activities including the Habitat Improvement Sale, the South Fork Road Rehabilitation Project, the Campground Hazard Salvage Sale, the Camp Creek Bridge Project, and the Teapot Timber Sale.

Sampling of aquatic macroinvertebrates was conducted at nine stations on the South Fork in 1981. Six of these correspond to 1980 measurement sites; the other three were added to provide for sampling areas with a greater percentage of fine substrate materials. Samples at the original stations indicate good water quality (as in 1980) and show some slight improvements over the previous year. At the new stations, clean-water species are less abundant and sediment-tolerant species more dominant.

Overall, the 1981 samples indicate good habitat with no detrimental effects occurring as a result of management activities during the previous year. The report includes data on stream velocities and temperatures at the nine sites in August and October 1981.

Measurements of channel substrate and stream depth at four sites on the South Fork during 1981 show the continuation of a slight but constant trend toward improvement since 1974. It appears that the channel is approaching a new equilibrium point that will be maintained unless a major event occurs.

Redd counts in 1981 on the South Fork, Johnson Creek, and Secesh/Lake Creek were 126, 45, and 53, respectively. These numbers are higher than the counts in 1979 and 1980, but below the 5-year averages for 1976 through 1980. At the South Fork chinook salmon trap, 400 adults and 124 jacks were captured, with 483,000 green eggs taken from 124 females.

A sediment basin in the Bear Creek Timber Sale accumulated 9.7 cubic yards in the 2 years preceding logging and roading (November 1977 to August 1979), and 5.5 cubic yards in the 2 years of logging and roading (August 1979 to September 1981).

South Fork Salmon River Monitoring Committee. 1983. Proceedings of the committee meeting; 1983 March 8; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 5 unnumbered pages plus appendixes.

Results of 1982 monitoring are as follows (some data published in references included elsewhere in this bibliography will not be repeated here): The 1982 water year was one of moderate to moderately high hydrometeorological stress in the South Fork area. Some failures occurred along the South Fork Road due to heavy runoff, but areas treated in the rehabilitation project show a continued trend toward greater stabilization. Only one mass movement occurred within the rehabilitated areas, a fill failure that delivered 75 cubic yards to the South Fork. Observed impacts are minimal during 1982 activities at the salvage sales, the Secesh-Maverick Creek Timber Sale, and the Camp Creek Bridge Installation. On the Teapot Timber Sale, harvested in 1980 and 1981, harvest units are in good to excellent condition, with good regrowth of herbaceous cover. Roads in the sale area are in good condition. One cut failure of 75 cubic yards occurred, but most of the material is detained behind obstructions. Postsale activities in 1982 take place with no major adverse effects. Data from four soil disturbance transects measured in 1982 show that bulk density had increased an average of 26 percent on compacted disturbed sites in the cutting units. A postsale review of the Teapot Sale results in a list of recommendations for future sales. Overall, the committee feels that the sale has been successful in terms of minimizing impacts through careful planning and supervision.

No major changes in water quality relative to previous years are apparent from samples taken from the Secesh, the South Fork, and the East Fork of the South Fork in 1982. Out of 16 cross-sections of the South Fork in the Payette National Forest measured in 1982, 10 exhibit degradation since 1981, five show aggradation, and one has no change. The highest percentage change in cross-sectional area is a 19.7 percent increase at Camp Creek. Included are data for temperatures and velocities measured in 1982 at the nine macroinvertebrate sampling sites.

Redd counts of summer chinook on the South Fork, Johnson Creek, and Secesh-Lake Creek in 1982 were 111, 37, and 65, respectively. These are close to the 1981 values. The Secesh-Lake Creek count is above the 5-year average (1977-1981) and the others are lower. Capture at the South Fork trap in 1982 was 502 adult summer chinook salmon and 48 jacks. Green egg take was 648,000 from 147 females.

In 1982, a few cases of minor erosion were observed during informal monitoring of the South Fork Road by Boise National Forest personnel. Minimal sedimentation, with total detention of sediment, occurred on the Bear Creek Timber Sale area. (A total of 7.2 cubic yards of sediment attributable to management activities was delivered to a sediment basin with a source area of 0.32 miles between 1981 and 1982.) Disturbances noted in previous years in the Roaring Creek Timber Sale area have stabilized in 1982. Some gullying occurred at the hatchery satellite facility. Erosion on existing roads in the Bad Bear Timber Sale area showed slight increases in 1982, but there is no evidence of increased sedimentation in the streams. Stored sediment, attributed to the Warm Lake - Landmark Road Reconstruction Project, was observed in some of the slower moving reaches of Warm Lake Creek. Significant stabilization of the creek occurs in areas directly affected by the project. Analysis of data from cross-sections of the South Fork on the Boise National Forest shows aggradation of five, degradation of two, and no change in one, from 1981 to 1982. For 1980 to 1982, five cross-sections have degraded while four have aggraded. The 1982 core sample data from six spawning areas show little change from the 1981 data.

Data on channel substrate, stream depth, and stream width conditions at the Stolle, Poverty, Krassel, and Glory study areas reveal little change since 1974, indicating poor recovery of these areas.

South Fork Salmon River Monitoring Committee. 1984. Proceedings of the committee meeting; 1984 April 11; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 16 p. plus appendixes.

Results of 1983 monitoring are as follows (published data reported elsewhere in this bibliography may not be included here): In the South Fork area, hydrometeorological stress during the 1983 water year is moderate.

Chinook salmon and steelhead spawning were concentrated between Poverty Pack Bridge and Miner's Peak Bridge. Steelhead spawning was also concentrated between Miner's Peak Bridge and Knox Bridge. Redd counts of summer chinook from the South Fork, Johnson Creek, and Secesh River-Lake Creek in 1983 were 185, 63, and 98, respectively, the highest values since 1978. As measured at the trap, 1983 is the highest year for fish return since operation began in 1980. Trapped fish included 937 adults. Eggs taken from 180 females totaled

750,634. Tagged fish had an average travel time of 25.6 days from Lower Granite Dam to the trap.

The percentage of fines on the surface of key spawning areas is unchanged in 1983. This and other measured variables, such as stream width and depth, indicate uniform conditions since 1974. Cross-section data (1978 to 1983) show that the upper section of the South Fork had 1.8 percent bed deposition, the middle section had 1.8 percent bed erosion, and the lower part had 4.8 percent bed erosion. The data reflect the major changes, approaching geologic proportions, occurring at the Oxbow area due to the breach of the Oxbow. The committee notes that changes in bottom materials below the Oxbow breach should not be attributed to management activities, and that impacts might be severe.

The 1982 to 1983 trend in nine cross-sections of the South Fork measured by the Boise National Forest is one of slight aggradation, with all sections showing less than 5 percent change in area. Because these are in reaches with relatively slow velocities, the aggraded material may have been flushed out of upstream reaches during high flows in 1982 and 1983. A few small slides were observed on the South Fork Road in 1983, but all of the eroded material was retained on the road. Presale monitoring of the Bad Bear Timber Sale area shows some rill and gully erosion on existing roads, probably due to bypassing of waterbars by flows. No sediment delivery to streams has occurred. Gullying near the holding ponds and two small cutslope slumps happened at the hatchery satellite facility in 1983. Revegetation of cutslopes and other disturbed areas is progressing well. In the Roaring Creek Timber Sale area, two sediment traps with source areas of 60 and 40 acres have impounded about 10 and 4 cubic yards, respectively, in 4 and 3 years. Both of these traps have roads in their source areas, and the first has a log landing as well. Revegetation problems are noted on the landing and a few road reaches. The committee concludes that management activities being monitored in the South Fork drainage by the Boise National Forest during the preceding years have not had any unacceptable impacts. Two years of above-average precipitation have enhanced revegetation rather than accelerated erosion.

On the Payette National Forest, measurements of 16 cross-sections of the South Fork indicate aggradation at nine and degradation at seven for 1982 to 1983. The Camp Creek site, which had been undergoing scour for the three previous years, had 19.35 percent aggradation. Changes there are attributed to the Oxbow breach and an upstream channel constriction. From 1978 to 1983, 12 stations show scour and four show fill. Measurements of stream temperature and velocity taken in 1983 at six South Fork sites are tabulated. No significant differences in percentage of surface fines are detected in Lick Creek above and below the area affected by the Secesh-Maverick Creek Timber Sale. Percentage of fines is not a reliable indicator of the quality of fish habitat. Cobble embeddedness and accumulated fines within spawning gravels are the critical factors in fish response. Techniques are being developed to measure these variables. Since implementation of the Land Management Plan, fish habitat appears to be stable upstream of the Oxbow area, with flushing of sediments in the downstream reaches. Fish habitat is generally not of high quality in the planning unit.

Minimal impacts were noted during 1983 visits to the Habitat Improvement Timber Sale and the salvage sales. Both the roads and the cutting units in the Teapot Timber Sale are revegetating and generating little sediment. Objectives of the South Fork Road Rehabilitation Project appear to be met in most cases by 1983. The road prism has become the major source of accelerated sedimentation, with rill and gully erosion common during rain and snowmelt events. For both the Secesh and Rainbow Timber Sales, 1983 was the first year of activity, and both sales are considered successful in terms of minimizing impacts. The Rainbow Sale had been designed with a maximum effort to reduce impacts. The effort included the use of helicopters.

South Fork Salmon River Monitoring Committee. 1985. Proceedings of the committee meeting; 1985 April 9; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 12 p. plus appendixes.

The following results of 1984 monitoring efforts are presented (data published in reports included elsewhere in this bibliography may not be included here): The 1984 water year was one of moderate climatic stress, with some localized high stress events, in the South Fork. High intensity rainstorms generated floods on Blackmare Creek (where 150 to 400 cubic yards of sediment were deposited in the stream) and on Rice Creek (where 1,500 to 9,000 cubic yards were deposited, and a tributary channel was scoured). The impacts in Rice Creek are not associated with any land management activities.

Redd counts of summer chinook in the South Fork, Johnson Creek, and Secesh River-Lake Creek were 165, 17, and 21, respectively, in 1984. Wild runs of salmon appeared to be in fairly poor condition, but this is not necessarily indicative of a trend. In 1984, 934 adults and 595 jacks were trapped, and 1,600,000 eggs were taken. The numbers of returning adults trapped increased between 1980 and 1984.

A steelhead study in the South Fork drainage began in 1984. Preliminary results of the first year's data show 407 redds, 70 percent of which were in the main stem. Survival from egg to fry at Poverty, where several redds were capped, was only 8 percent. Heavy embeddedness of some rearing areas is apparent.

Project monitoring efforts by the Boise National Forest in 1984 reveal little in the way of new problems. Despite 3 consecutive years of above average precipitation and streamflow, no unacceptable impacts have been observed from any of the monitored activities.

Project monitoring continued in the Payette National Forest in 1984. Conditions are good at the Secesh Timber Sale (ground-based) and the Rainbow Timber Sale (helicopter). Some drainage problems, resulting in sediment delivery of 10 cubic yards to Homedale Creek, occur on roads in the Teapot Timber Sale area. The South Fork Road continues to exhibit rill and gully formation during rain and snowmelt periods. This is due largely to rutting, which concentrates surface runoff. A dust abatement material applied to the road in the Poverty Burn area reduced rilling during storms and controlled the dust.

However, it also produced a slippery surface during storms, and some rutting occurred.

Baseline hydrologic monitoring continued on the Boise and Payette National Forests in 1984. The South Fork cross-sections on the Boise Forest show no strong trend. Most of the South Fork cross-sections measured on the Payette Forest have a change in area of less than 2 percent for 1983 to 1984. The trend for the Payette sample appears to be one of scour for 1978 to 1984, with the exception of the Lower Oxbow site, which is filling due to the Oxbow breach. However, an analysis of variance shows no significant change in channel elevation at any of the Payette sites since 1977. Elevation data are considered more meaningful than cross-sectional area data in assessing streambed changes. Good long-term streamflow data are available for the South Fork, and frequency distributions have been developed for annual and peak flows. The water quality samples taken from the Secesh, the South Fork, and the East Fork of the South Fork in 1984 show elevations in some of the values. These could possibly be the result of errors in analysis rather than real changes. Other baseline hydrologic monitoring reveals a small mass failure on the Two Bit - Six Bit Road (retained on the road) and a small to medium blowout of a draw on Kline Mountain.

Baseline fish habitat monitoring conducted by the Payette National Forest in 1984 includes studies of macroinvertebrates, cobble embeddedness, and core samples. The macroinvertebrate species monitored were chosen because of their sensitivity to sedimentation. Densities of the sensitive species do not increase with an increase in fine sediment. These results concur with published studies that show no change in densities until a threshhold of 30 percent fines, or two-third cobble embeddedness, is exceeded. Embeddedness was high in rearing areas of the main stem and moderate in the Secesh and the East Fork South Fork. No change in embeddedness is observed in Blackmare Creek following the blowout. Regression analyses of percentage of fines for 1975 through 1984 show decreasing trends at Dollar, Poverty, Oxbow, and Glory. For all these except Glory, the trend is less pronounced in the later years (1982 to 1984). Stolle shows no significant difference from a zero slope, while Johnson Creek shows an increasing trend. There is an increase in fines at the Stolle site following the Rice Creek flood, although the substrate appears to be clean.

South Fork Salmon River Monitoring Committee. 1986. Proceedings of the committee meeting; 1986 April 21; Boise, ID. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 3 p. plus appendixes.

Results of 1985 monitoring are as follows (data in references included elsewhere in this bibliography may not be reported here): Water year 1985 is one of low to moderate hydrometeorological stress in the South Fork drainage, although high-intensity storms impact some isolated areas.

Fish studies conducted by the Idaho Department of Fish and Game show counts up in 1985 for all populations. Summer chinook redd counts for the South Fork, Johnson Creek, and Secesh River-Lake Creek were 323, 75, and 105, respectively. These values are more than twice the 5-year averages for 1980 through 1984. The habitat is still underseeded. Trapping operations captured 1,409 adults and 828 jacks, and 2,073,546 eggs were taken. Densities of steelhead trout, cutthroat trout, bull trout, and chinook salmon are all significantly related to embeddedness values. The findings indicate that sediment limits rearing populations of resident and anadromous fish in the South Fork.

Regression analyses for core sampling data collected by the Boise National Forest at six spawning areas show trends not significantly different from a zero slope at Stolle, Dollar, Poverty, and Oxbow. The latter three areas have negative trends for the previous years. Glory exhibits a negative trend (indicating decreasing fine sediments), while the trend at Johnson Creek is positive (indicating an increase in fine sediments). Observations at Rice Creek show significant movements of bed and suspended loads. Suspended sediments from Rice Creek are apparent in the South Fork below the confluence of the streams but are not observed at the Stolle spawning area. Bedload sediments are stored in the Rice Creek channel. Two road stabilization projects and two bank stabilization projects carried out in 1985 are expected to reduce sediment deposits into the South Fork system.

Analysis of variance results for the Boise National Forest core sample data show no detectable time trend at Stolle (although the means are significantly different over time). However, Poverty, Glory, Oxbow, and Johnson Creek all show time trends. The data confirm that percentage of fines is increasing at most sites.

Surveys of the South Fork cross-sections on the Boise National Forest show a slight decrease in area at Lower and Upper Stolle, possibly in response to the Rice Creek flood of August 1984. A cross-section of Rice Creek shows a 20 percent decrease in area from 1984 to 1985 due to sand deposition. Other 1985 monitoring activities conducted by the Boise National Forest reveal minimal adverse management impacts.

Only three of 16 cross-sections measured by the Payette National Forest showed changes greater than 3 percent between 1984 and 1985. The only site that shows an area change in excess of 3 percent since implementation of the South Fork Management Plan (1978 to 1985) is Lower Oxbow. Changes there are attributed to the Oxbow breach. Chloride values of the 1985 water quality samples from the South Fork, the Secesh, and the East Fork of the South Fork are low, in contrast to the high values reported in 1984. None of the values for any of the measured factors are unusually high.

Two sediment traps on the inside ditch of steep sections of the South Fork Road in the Payette National Forest were effective in collecting considerable amounts of sediment, while one on a road section with a lower gradient caught little sediment. Erosion from the road prism due to surface runoff continues to be the greatest problem associated with the road. The road constitutes a major source (if not **the** major source) of sediment deposits into the South Fork. Other monitoring conducted by the Payette National Forest in 1985, including monitoring of the Secesh Timber Sale, reveals few problems.

Stowell, Rick; Espinosa, Al; Bjornn, Ted C.; Platts, William S.; Burns, Dave C.; Irving, John S. 1983. Guide for predicting salmonid response to sediment yields in Idaho batholith watersheds. Ogden, UT: U.S. Department of Agriculture, Forest Service, Northern and Intermountain Regions. 95 p.

As an aid to the forest planning process, researchers sought a standardized method for predicting the effects of sediment on stream habitat and fish populations within the Idaho batholith. This series of models is based primarily upon relationships developed in laboratory studies. Using watershed estimates of sediment yield over natural yield, this report offers equations predicting channel embeddedness, percentage of fines by depth, and changes in fish population. The user may then assess the impacts upon fishery habitat and create management-mitigation options. The authors feel that the model could be revised and updated for application to other geographic regions. The South Fork Salmon River is used as an example of watershed recovery under an intensive timber management program.

Tappel, Paul D.; Bjornn, Ted C. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. North American Journal of Fisheries Management. 3: 123-135.

A new method for describing the size composition of salmonid spawning gravel has been developed from stream gravel samples of the South Fork Salmon River, ID, and the Clearwater River, WA. Distributions of particle sizes less than 25.4 mm consistently plot as straight lines on log-probability paper. Because of the lognormal distribution of the particle sizes in this range, the size composition of material smaller than 25.4 mm is closely approximated by two points on a regression of cumulative particle size distribution. The two size classes that best reflect the composition of the spawning gravel size are the percentage of the substrate smaller than 9.50 mm and the percentage smaller than 0.85 mm. Laboratory tests focus on chinook and steelhead survival as compared to substrate composition. (Adapted from authors' abstract.)

Thompson, Richard A.; Skabelund, Paul H.; Kulesza, Norbert C. 1973. Soil-hydrologic reconnaissance, McCall Ranger District, Payette National Forest. McCall, ID: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest. 227 p.

This report follows the same format, and uses much of the information from, previously published soil-hydrologic reconnaissance reports from the Cascade and Krassel Ranger Districts (USDA FS 1969, 1970). Like those reports, it also draws upon the South Fork Salmon River Special Survey, Soils and Hydrology Report (Arnold and Lundeen 1968).

Fifty-five landtypes (the basic unit of the report) are identified within the District and are placed into four geomorphic groups, the same as those described for the Cascade District report. Strongly glaciated lands make up 35.9 percent of the area and include 23 landtypes. Periglaciated lands include six landtypes and account for 18.9 percent of the area. There are 15 landtypes within the fluvial lands, which constitute 32.8 percent of the area. Depositional lands include 11 landtypes and 12.1 percent of the area.

Torquemada, R. J.; Platts, W. S. 1983. Poverty spawning area - South Fork Salmon River, Idaho; Progress Report 1, 1977-1982. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Sciences Laboratory, Boise, ID. 36 p.

Substrate conditions in the Poverty spawning area over a 6-year period indicate that stream channel surface substrates have stabilized at levels that provide for successful spawning. Subsurface fines show a slower rate of improvement and may limit salmonid production. Stream temperature data are included. Monitoring of the Poverty spawning site was terminated in 1983, so subsequent reports have not been written.

Ulliman, Joseph J.; Singh, Harnek; Megahan, Walter. 1983. Remote sensing detection for planning on the Salmon River. In: Proceedings, 1982 convention of the Society of American Foresters; 1982 September 19-22; Cincinatti, OH. Publication 83-04. Washington, DC: Society of American Foresters: 133-137.

The researchers have developed an aerial photo interpretation scheme for detecting riverbottom surface sediments and for planimetrically mapping various size classes using historical aerial photography. At three sites on the South Fork of the Salmon River, sand, gravel, cobble, rubble, and boulders are mapped on small-scale aerial photos of 1946, 1947, 1952, 1965, and 1972, and on large scale aerial photos of 1965, 1972, 1976, and 1979. Cross-section profiles are also measured from the photos with a limited degree of accuracy. Both aerial photo and ground data are statistically analyzed and used to display time trend curves for the sediments. A computer mapping program is then used to enhance the graphic display of the data. Average error of the aerial photo-interpreted data ranges between 10 and 23 percent depending on which of two types of ground data are used. (Adapted from authors' abstract.)

U.S. Department of Agriculture, Forest Service. 1962. South Fork Salmon River and tributaries stream habitat survey. Boise, ID: Boise National Forest. 31 p.

Crews surveyed 25 miles of the main stem South Fork Salmon River and 40 miles of its tributarys streams with respect to fishery habitat. Variables measured include pool size, large surface substrates, bank vegetation, depth, instream vegetation, velocity, and bank stability.

U.S. Department of Agriculture, Forest Service. 1969. Soil-hydrologic reconnaissance of Cascade Ranger District, Boise National Forest. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Region, Boise National Forest. 150 p.

This inventory of soil and water resources of the District, intended to provide information for multiple-use planning. The report draws heavily on the South Fork Salmon River Special Survey, Soils and Hydrology (Arnold and Lundeen 1968). The South Fork Survey area includes about two-thirds of the District.

The basic unit of the report is the landtype. Researchers identify 35 landtypes on the District and put them into four broader categories of geomorphic groups. Each landtype is described by location, management zone, extent, topography, geomorphic features, bedrock characteristics, vegetation, soils, and management qualities. The report also includes a table of landtype characteristics, hydrologic qualities, erosion potential, and stability hazards.

The first geomorphic group, strongly glaciated lands, includes 11 landtypes and comprises 28.4 percent of the area. These lands occur in the headlands of most of the drainage tributaries of the South Fork Salmon River. Strongly glaciated lands are the chief water producers and have the greatest snow accumulations in the area. They are considered to be relatively stable for road construction purposes, although construction of road cuts in the hard unweathered rock can be difficult. These lands are the poorest timber producers.

The second geomorphic group, weakly glaciated uplands, includes three landtypes and comprises 15 percent of the area. Mass wasting is the dominant natural erosion process. Hydrologic and engineering characteristics are generally favorable.

Fluvial lands, the third geomorphic group, includes 13 landtypes and comprises 47.9 percent of the area. These lands are characterized by moderately well to well-weathered quartz monzonite bedrock (which spalls upon exposure) and steep slopes.

The final geomorphic group is depositional lands, with eight landtypes and 8.7 percent of the area. These lands are important in the storage of water from the higher elevations. Road construction potential is excellent, with a few precautions.

U.S. Department of Agriculture, Forest Service. 1970. Soil-hydrologic reconnaissance, Krassel Ranger District, Payette National Forest. McCall, ID: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest. 148 p.

This report has the same objectives and format as the soil-hydrologic reconnaissance report for the Cascade Ranger District (USDA FS 1969). The content is also largely the same. This report also draws heavily on the South Fork Salmon River Special Survey, Soils and Hydrology Report (Arnold and Lundeen 1968), as well as the Hydrologic Analysis Report of the Zena Creek logging study area (Jensen and Finn 1966). The District is entirely in the South Fork Salmon River drainage.

The basic unit of the report is the landtype. Researchers identify 35 landtypes on the District and put these into four geomorphic groups. The geomorphic groups are the same as those described in the Cascade District report; therefore, the information will not be repeated here. The geomorphic groups of strongly glaciated lands, weakly glaciated uplands, fluvial lands, and depositional lands include 11, 3, 13, and 8 landtypes, respectively, and make up respective areas of 36.4, 6.1, 49.0, and 8.5 percent of the total area.

U.S. Department of Agriculture, Forest Service. 1985. South Fork of the Salmon River appendix for the Payette and Boise National Forests proposed land and resource management plans. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region. 151 p.

This overview of the South Fork Salmon River and the management direction and activities for the entire drainage includes reviews and summaries for: (1) location, topography, fish, wildlife, and wilderness; (2) geographic development, development history, and land management plans for the area; (3) anadromous fish, environmental consequences to fish habitat, and fish/sediment relations from 1945 to present; (4) relative impacts of old vs. new logging techniques; and (5) resource outputs, activities, costs, and benefits.

The bulk of the appendix is material highlighting the proposed and probable management practices, activity schedules, and monitoring plans established by the Boise and Payette National Forests as these affect the South Fork Salmon River drainage. Drawn from the 1985 draft land management and resource plans of the two Forests, this information is presented by management area.

Welsh, Thomas L. 1969. South Fork of the Salmon River weir counts, harvest and escapement study, 1968. Boise, ID: Idaho Department of Fish and Game. 15 p.

Summer run chinook salmon were counted on the South Fork Salmon River at a temporary weir from 1964 to 1968. Counts range from a high of 3,300 in 1966 to a low of 1,500 in 1968. Salmon harvest ranges from a high of about 4,000 fish in 1960 to a low of 91 in 1968. Angling pressure falls with reduced harvest from a high of 12,500 angler days in 1962 to 400 angler days in 1968. Sex and age composition data are included.

Wendt, G. E.; Thompson, R. A. 1978. Soil inventory key to South Fork Salmon River Land Management Plan. In: Forest soils and land use: Proceedings, fifth North American forest soils conference; 1978 August; Fort Collins, CO. Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences: 214-224.

Determining a suitable mix of resource products is complicated by steep slopes and erosive soils in the South Fork of the Salmon River Planning Unit. The initial environmental statement and land management plan are appealed, resulting in specific direction for a new land management plan and environmental statement that quantify effects of management activities on the anadromous fish habitat.

Soil mapping units are used as the initial basis for development of analysis units, management areas, and management units. Soil mapping units, along with research data, are used to develop quantified average sediment estimates for each analysis unit. In addition, they are used as a basis for estimating quantified impacts from various management activities and for allocating areas of land to various resource uses.

Using the quantified values, a computer program generates a number of alternatives and displays the impact of each relative to the tolerable levels of sediment established for the anadromous fish spawning areas.

The blending of numerous talents and resources produces an environmental statement and land management

plan with quantified resource information that visibly displays the land management decision-making process. (Adapted from authors' summary.)

Williams, Ted. 1981. Keeper of the rivers. Gray's Sporting Journal. South Hamilton, MA: Gray's Sporting Journal, Inc.; 6(1): 83-91.

This article reviews the current condition of several rivers and their watersheds as impacted by the Forest Service and forestry practices. It provides a history of the degradation of the South Fork Salmon River and its fisheries.

Zena Creek Logging Study Committee. 1963. Minutes of the committee meeting; 1963 June 4-5. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Region, Payette National Forest, McCall, ID. 5 p. (p. 1-2).

Sediment yields from the Tailholt drainage for 1961, 1962, and 1963 are 8.9, 14.8, and 15.2 tons per square mile, respectively. Suspended sediment yields are low, even during periods of high flow such as the 1962 fall rains and the 1963 spring runoff, which have measured discharges of 9.0 and 7.0 cubic feet per second, respectively. Sediment yields from the Circle End watershed are lower than those from Tailholt. Circle End has a measured yield of 10 tons per square mile in 1963, the first full year of measurement. Circle End watershed has granitic soils with a lower clay content and greater ground cover than the Tailholt watershed.

Seyedbagheri, Kathleen A.; McHenry, Michael L.; Platts, William S. 1987. An annotated bibliography of the hydrology and fishery studies of the South Fork Salmon River. Gen. Tech. Rep. INT-235. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 27 p.

A brief summary of the land management history of the South Fork Salmon River (Idaho) watershed includes citations and annotations of published and unpublished reports of fishery and hydrology studies conducted in the South Fork drainage for 1960 to 1986.

KEYWORDS: aquatic habitat, sedimentation, erosion, anadromous fish, logging, forest road construction, Idaho batholith

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

United States Constitution 1787 1987 Bicentennial We the People

United States
Department of
Agriculture

Forest Service

**Intermountain
Research Station**

General Technical
Report INT-236

Forest Habitat Types of Northern Idaho: A Second Approximation

**Stephen V. Cooper
Kenneth E. Neiman
Robert Steele
David W. Roberts**

RESEARCH SUMMARY

A land classification system based upon potentially climax natural vegetation has been developed for the forests of northern Idaho. The system is based on reconnaissance and detailed sampling of approximately 1,100 stands. The habitat type concept of Daubenmire is used to construct a hierarchical taxonomic classification of forest sites. A total of eight climax series, 49 habitat types, and 60 additional phases of habitat types are defined. A dichotomous key, based on indicator species used in development of the classification, is provided for field identification of the syntaxonomic units.

In addition to site (forest environments) classification, descriptions of mature plant communities are provided, accompanied by tables to portray the distribution of important species. Potential timber productivity and climatic characteristics are also provided for the habitat types and phases. Preliminary implications for natural resource management are included based on field observations and published information.

ACKNOWLEDGMENTS

We thank the Northern Region of the Forest Service, U.S. Department of Agriculture, for its financial support, administered through a cooperative agreement with the Intermountain Research Station and the Montana Conservation and Experiment Station (University of Montana). Robert D. Pfister (University of Montana) and Charles A. Wellner (Intermountain Station, retired) initiated, secured funding, and provided major guidance to this project; for their efforts we are sincerely appreciative. Wellner was especially helpful in sharing his unparalleled knowledge of Idaho's forests and appropriate sampling locations.

Many people have assisted this effort, but foremost among them were our field assistants and computer technicians Brian Steele, Mike Sweet, and Patricia Patterson. Those generously donating vegetation data were Dr. James Habeck (University of Montana); Rex Crawford and Frederic Johnson (University of Idaho); Stephen F. Arno (Intermountain Station); and Rexford and Jean Daubenmire (Washington State University, retired).

Those contributing their knowledge in the fields of soils and geology (primarily through parent material identification) were Ken Fry (Lolo National Forest); Gary Ford, Jerry Niehoff, and Lewis Monk (Idaho Panhandle National Forests); and Neil Peterson, Charles Weisell, and Don Larson (Soil Conservation Service, Moscow, ID).

Identification and verification of difficult plant specimens were provided by Peter Stickney (Intermountain Station) and Douglass Henderson (University of Idaho).

Providing technical commentary were Robert Pfister (University of Montana); Stephen Arno (Intermountain Station); William Stewart, Wendel Hann, and John R. "Bob" Naumann (Northern Region); Frederic Johnson (University of Idaho); and David Gruenhagen (Idaho Department of Lands). Many land managers, both public and private, assisted in field sampling and provided suggestions during the classification's development.

THE AUTHORS

STEPHEN V. COOPER, research forester with the University of Montana when this study was initiated, was assigned major responsibility for the conduct of this study. He has coauthored a number of habitat type classifications for the Central and Northern Rocky Mountains and was primary author and analyst of the *Abies grandis*, *Abies lasiocarpa*, and *Tsuga mertensiana* series in this manual. He holds B.S. (Union College, Schenectady, NY) and M.S. (State University of New York, Albany) degrees in biology and a Ph.D. in botany from Washington State University, Pullman.

KENNETH E. NEIMAN, forest ecologist with the Clearwater National Forest detailed to the Intermountain Research Station, Moscow, was principal coinvestigator for this study. He has previously developed community classifications with the U.S. Forest Service Pacific Northwest Region Ecology Program in south central Oregon. He was the primary analyst and author of the *Thuja plicata*, *Tsuga heterophylla*, *Pseudotsuga menziesii*, *Pinus ponderosa*, and *Pinus contorta* series. He earned B.S. (range management) and M.S. (forest and range management) degrees from Washington State University and a Ph.D. in forest ecology from the University of Idaho, Moscow.

ROBERT STEELE is a research forester on the Douglas-fir and Ponderosa Pine Ecosystems Research Work Unit, Boise, ID. He has published extensively on the classification and succession ecology of forest ecosystems of the Intermountain West. He was responsible for field sampling and accumulating a large data base from the Nez Perce and Clearwater National Forests, and produced a preliminary classification for the Nez Perce National Forest. He received B.S. (forest management) and M.S. (forest ecology) degrees from the University of Idaho, Moscow.

DAVID W. ROBERTS, currently with the Department of Forestry and Outdoor Recreation, Utah State University, Logan, initiated the field sampling and authored our data analysis computer programs. He received B.S. and M.S. degrees (forestry) from the University of Montana and a Ph.D. (plant ecology) from the University of Wisconsin, Madison.

December 1987

Intermountain Research Station
324 25th Street
Ogden, UT 84401

CONTENTS

TABLES

Page

FIGURES

Page

Forest Habitat Types of Northern Idaho: a Second Approximation

Stephen V. Cooper
Kenneth E. Neiman
Robert Steele
David W. Roberts

INTRODUCTION

Northern Idaho's forest vegetation presents a complex array in composition and structure. To facilitate effective management of these lands, a classification is needed to reduce the diversity to a reasonable number of units. Natural classifications, in contrast to technical classifications of specific applicability such as timber types or cover types, are based on natural relationships and have a broad application, serving a multiplicity of management needs. Natural classifications such as habitat types (Daubenmire and Daubenmire 1968) reflect ecological patterns and thus accommodate the greatest number of applications.

The implementation of habitat type (h.t.) or similar approaches (based on plant associations) to forest site classification has steadily progressed (since Daubenmire's [1952] pioneering effort), with the publication of more than 30 such classifications in the Western United States (Pfister 1981). This approach has proven useful in forest management and research (Hall 1980; Layser 1974; Pfister 1980). Its widespread use recognizes the need to emphasize management of ecosystems rather than individual resources. It answers the need among specialists for a common medium to guide communication, management decisions, and research.

The Daubenmires' (1968) classification of forest h.t.'s in eastern Washington and northern Idaho has proven eminently useful, serving as a model for subsequent classifications. Nevertheless, studies for contiguous areas (Montana, Pfister and others 1977; central Idaho, Steele and others 1981) revealed that the Daubenmires' original h.t. classification could be refined to better reflect the full range and diversity of forest environments. The considerable amplification in the number of h.t.'s delineated in the Nez Perce National Forest preliminary classification (Steele and others 1976), an area addressed by the Daubenmires' (1968) original study, indicated the need for more intensive sampling on the remainder of the Daubenmires' core area. The studies of Henderson and Peter (1981) and Hemstrom and others (1982) in coastal forest types similar to those of northern Idaho have shown that intensive sampling (both in the number of plots per unit area and quantity of site data recorded) results in classifications having greater management utility and less ambiguity in application (since fewer environments are left uncategorized). They sampled at approximately one plot per section, whereas the Daubenmires' (1968) sampled at one plot per 200 sections (one plot per 500 sections on the Nez Perce National Forest). Personnel on National Forests and in research units have sometimes found that the Daubenmires' (1968) classification was too general a treatment for the ecological diversity encountered or that the site simply did not fit the key or description. This is not to fault Daubenmires' work. Rather, the "state of the art" in habitat typing has advanced to where foresters, including some initially resistant to the concept of a classification with 22 units, now want an even more detailed classification.

Study Objectives and Scope

Rather than extrapolate from classifications of adjacent areas or work with data-deficient, local, informally revised classifications, a decision was made to refine the Daubenmires' classification. To this end a cooperative study was initiated in 1980 between the Northern Region USDA Forest Service and the Intermountain Research Station. Objectives of this study were to:

1. Develop a refined classification of habitat types for forested lands of northern Idaho based on potential climax vegetation (plant associations).
2. Describe the general site characteristics, topography, microclimate, and soils for each habitat type.
3. Describe the vegetational composition of mature and old-growth stands of each type.
4. Provide observations on successional development, estimates of potential timber productivity, and general biological observations potentially useful for management.

This classification pertains to that portion of Idaho from the Salmon River north to the United States-Canada border (fig. 1). This area encompasses approximately 12.2 million acres (4.9 million ha), of which 6.4 million acres (2.6 million ha) occur on National Forest lands (Nez Perce, 2.2 million acres [0.9 million ha]; Clearwater, 1.7 million acres [0.7 million ha]; St. Joe, 0.9 million acres [0.4 million ha]; Coeur d'Alene, 0.7 million acres [0.3 million ha]; and Kaniksu, 0.9 million acres [0.4 million ha]). Most sampling was conducted on National Forest lands. Flood plains and riparian stringers dominated by broad-leaved trees were not sampled or classified. *Populus tremuloides*-dominated stands in the core area were considered to be short-lived seral stages; hence, no potential climax series (see Synecological Perspective and Terminology section) is recognized for this species.

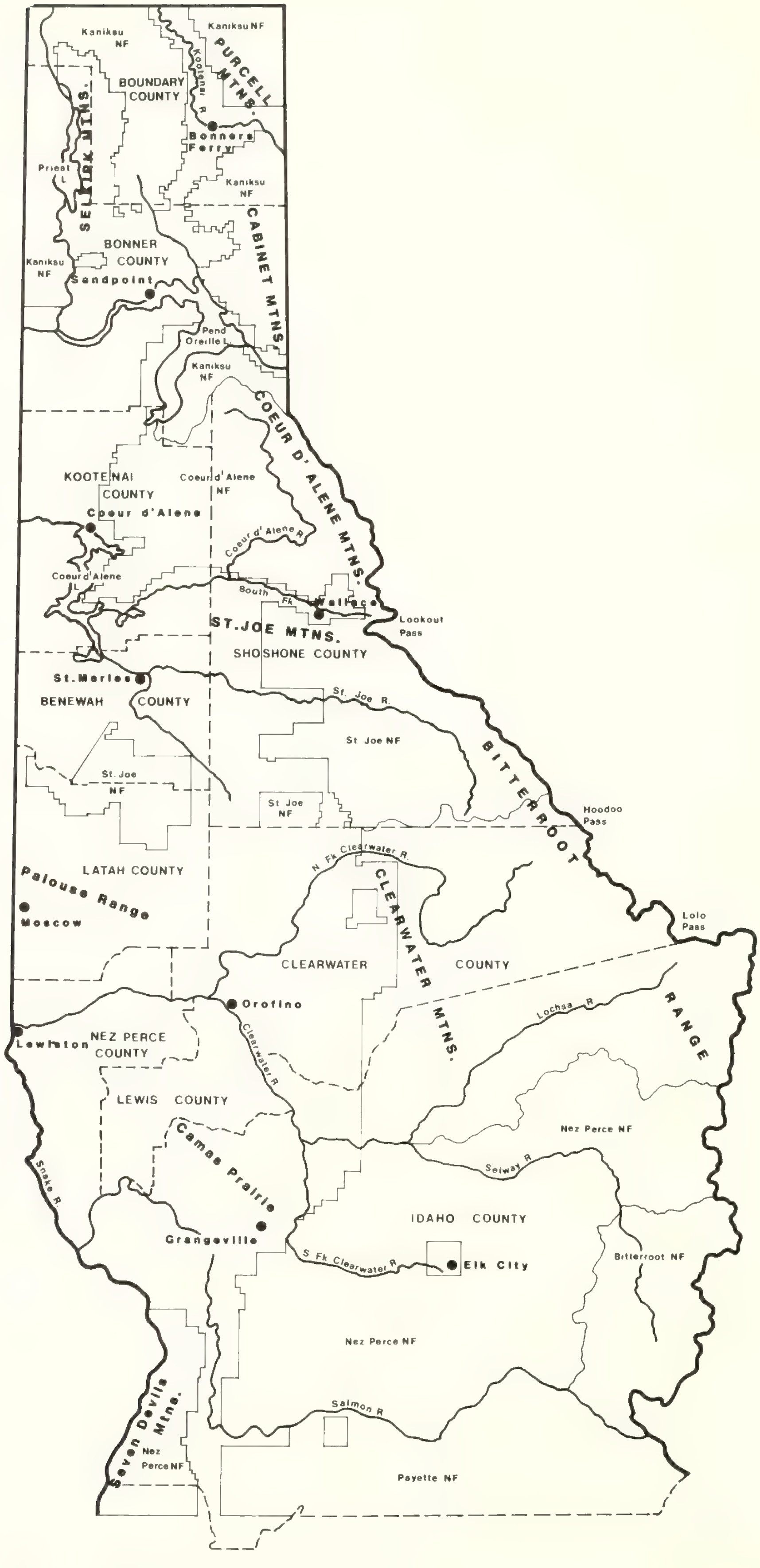


Figure 1—Northern Idaho study area indicating geopolitical units and selected physiographic features.

METHODS

Field Methods

Our goal was to efficiently sample the complete environmental spectrum of Idaho's coniferous forests north of the Salmon River for which we could locate mature and old-growth forests. These goals precluded the use of random and systematic sampling and much reduced the intensity at which broad valley bottoms (largely privately held) were sampled. Mueller-Dombois and Ellenberg (1974) have termed an approach similar to ours "subjective, but without preconceived bias." Plots were not chosen with regard to their position in any classification, extant or envisioned, or by applicability to specific management considerations. This philosophy was adhered to at the three major steps of locating plots: (1) selecting road transects, (2) choosing stands, (3) situating the macroplot within the stand.

Road transects were chosen that traversed as wide a range in environmental conditions as possible in a given area while simultaneously satisfying stand successional stage and nondisturbance criteria. On a given elevational transect, plots were generally spaced 300 to 400 ft (90 to 120 m) vertically, and areas were chosen that offered maximum contrast in a minimum distance; for example, contrasting north and south slopes or toe-slope versus ridgeline. Transect sampling offers indispensible insights into forest community patterns that can be incorporated into h.t. descriptions.

For locating plots within stands the determining factor was homogeneity of the overstory (distribution by species and size classes), understory (distribution by species evaluated in terms of coverage), and site parameters. The plot center was relocated if ecotones, microsites, or recent disturbance were detected. Recognition of ecotones is the single most subjective criteria; it demands field experience and familiarity with the ecological responses of the species present.

In the course of our work, we switched from a 375-m^2 (4,032-ft^2, ≅0.09-acre) circular or rectangular plot to a circular 500-m^2 (5,379-ft^2, ≅0.12-acre) plot; the larger plot size helped reduce bias detected in preferentially locating plots in high-basal-area stands. A complete inventory for trees taller than 4.5 ft (1.37 m) was made, tallying species by 2-inch (5-cm) diameter classes on the 500-m^2 (≅0.12-acre) plot. Reproductive success for tree species was sampled by recording trees between 0.5 and 4.5 ft (0.15 and 1.37 m) in height on a 50- or 100-ft^2 (4.6- or 9.3-m^2) circular plot at the center of the macroplot.

We visually estimated cover of all vascular plant species, using Daubenmire's (1959) eight cover classes (+ = present in stand but not in plot, T = 0 to <1 percent cover, 1 = 1 to <5 percent, 2 = ≥5 to <25 percent, 3 = ≥25 to <50 percent, 4 = ≥50 to <75 percent, 5 = ≥75 to <95 percent, 6 = ≥95 to 100 percent). Although the coverages were estimated for the entire macroplot, the accuracy of this method approaches or exceeds that of the 50 small (20- by 8-inch [50- by 20-cm]) quadrats per macroplot originally specified by Daubenmire (1959), and it more than doubles the number of stands sampled per day. Cover class values are used directly in association tables, ordinations, and other objective data analysis routines.

To estimate site potential, three to five (or more where variability warranted) dominant or codominant trees per species were measured for height, age, and diameter at breast height (d.b.h.) (see Timber Productivity section for tree selection criteria). Occasionally, as on the more moist sites in the *Thuja plicata* series (high percentage of trees with root rot), or on overstocked sites (stagnated), and in near-climax stands (stagnation, root and butt rot, crown damage) there were no suitable site trees. Maximum heights only were determined for some old-growth stands.

Near plot center, a soil pit was hand-excavated to a control depth of 40 inches (approximately 1 m) or to bedrock and the profile described according to prescriptions of the Soil Survey Manual (Soil Survey Staff 1981). Samples of each horizon and the parent material were saved and air dried for laboratory analysis. Litter, fermentation, and humus layers were measured at three randomly chosen locations on the plot.

Site factors measured included elevation, slope aspect and inclination, position on slope, microrelief, and landform; location coordinates (township, range, section) and road mileage to relocatable site were also recorded. Observations were made regarding insects and tree pathogens, animal use, fire history, extent of the stand, its position relative to surrounding vegetation types and environmental conditions, and, when available, seral communities developing on similar sites. The rationale for employing these field procedures is detailed by Pfister and Arno (1980).

One field team in a very abbreviated 1980 field season sampled 96 stands on the Kaniksu and Coeur d'Alene National Forests. During the summers of 1981 through 1984, two field crews sampled a total of 620 stands from the whole study area, including the Nez Perce National Forest, which R. Steele and S. Arno had previously sampled (106 stands) in preparation of a preliminary h.t. classification (Steele and others 1976). Whenever possible, plots from preceding studies were incorporated into our data base, including 226 collected by James Habeck (University of Montana) on the Selway-Bitterroot Wilderness, 86 from Daubenmire and Daubenmire's (1968) Idaho locations, several mature forest plots donated by S. Arno from a succession study, 42 from R. Steele's study (1971) on the lower North Fork Clearwater River, and 51 from R. Crawford and F. Johnson (University of Idaho) in an area east and south of Grangeville. The combined data set represents a sampling intensity of one plot per 18 sections (11,500 acres [4,700 ha]).

Nearly all the cited investigators used the same plot size (375 m^2), techniques, and cover classes for estimating vegetative cover; their studies differed only in intensity of soil description and measurement of site index. Thus, for constructing the classification, all plots were of nearly equal utility; but for formulating management implications, estimating productivity, and ascertaining the relationship of h.t.'s to one another and environmental gradients, the set of useful plot data was heterogeneous and much reduced.

Office Procedures

Soil parent materials were determined by professional geologists Carol Hammond (Intermountain Research Station, Moscow, ID) and Ken Fry (Lolo National Forest, Missoula, MT). Textural class determinations and training of our staff was provided by soil scientists Richard Kline (Northern Region, Missoula), Maynard Fosberg (University of Idaho, Moscow), and Neil Peterson (Soil Conservation Service, Moscow). Air-dried samples from each horizon were weighed, sieved at 0.08 inch (2 mm), and reweighed for determination of gravel content (percentage by weight). The soil separate was analyzed for dry and wet color, texture, consistency, and saturated-paste pH.

Data analysis and development of our classification follow the procedures and rationale detailed by Pfister and Arno (1980); the following section is a condensation thereof, with our exceptions to their approach noted. One of our major considerations was that the resulting classification should be a refinement of a previous, well-accepted work in forest classification by Daubenmire and Daubenmire (1968). The classification should also mesh with classifications produced for contiguous areas—central Idaho (Steele and others 1981) and Montana (Pfister and others 1977)—which had been habitat typed according to the approach we have subscribed to in this publication. We follow their ecological classification where their interpretations agree with northern Idaho data.

We assumed that the tree series (potential climax) should be provisionally accepted as delineated in previous studies cited above. Therefore, we stratified our stands into the indicated tree series; within each series, plots were grouped into possible associations by their similarities in vegetal composition (by species, constancy, and coverage) and correspondence to classifications from contiguous areas. In order to group those stands with the greatest overall similarity, synthesis tables (Mueller-Dombois and Ellenberg 1974) were generated by computer and rearranged numerous times.

Printing of elevation, slope, aspect, etc., and geographic location as stand headers on synthesis tables facilitated the comparison of site factors by stand groupings in the quest for a close correspondence between environmental-geographic patterns and taxonomic units.

Mathematical ordinations based on index of similarity (Bray and Curtis 1957) were applied to each series as a graphical comparison of stand composition and relative placement on apparent environmental gradients. These ordinations were used in evaluating the subjective stand groupings and the merits of given species as indicators. Ordinations also provided insight for interpreting vegetation-environment relationships.

Vegetal characteristics for the habitat types and phases were identified and described, and a dichotomous key was then designed for their identification. The key was tested using each sample stand. We then revised the key to accommodate essentially all stands. Terminology for naming the types and wording of the key were adjusted where warranted to reflect the correspondence between this and extant classifications. When consistent vegetal differences within a habitat type were correlated with relatively minor environmental dissimilarities, a phase level was designated to categorize this variability (see Syntaxonomic Perspective and Terminology section for definitions). A tentative key was developed for field testing the summers of 1982 and 1983, and user responses were requested and incorporated where appropriate.

The geographic distribution, relative importance, distribution in relation to key site factors and other h.t.'s, characteristic vegetal features, and phase descriptions and their distinctions are described for each habitat type. The obvious management implications, those that generally follow from considering a habitat type's environmental and vegetational characteristics (including productivity) are addressed. This classification serves as a repository of information useful for generating "site specific" management guidelines—in short, an information storage and retrieval system.

Taxonomic Considerations

In the course of sampling, several hundred voucher specimens were collected. The better collections were deposited in the herbaria of the Intermountain Research Station at Missoula, and the University of Idaho, Moscow. Difficult specimens were verified or identified by P. Stickney (USDA Forest Service, Intermountain Station, Missoula, MT) or D. Henderson (University of Idaho, Botany Department). Nomenclature follows Hitchcock and Cronquist (1973).

A continually vexing problem is discriminating between *Vaccinium globulare* and *V. membranaceum.* Stickney (n.d.) in Montana, and Steele and others (1981) in central Idaho have found most material best conforms to *V. globulare.* But Steele and others (1981) cited their northernmost areas as supporting populations with intermediate characteristics. We have found insufficient flowering material to ascertain for our area the relative proportions of the two taxa in observed populations, but based on leaf morphology most material appears to agree with *V. globulare.* Therefore, we have used *V. globulare* to designate these populations (species) in the h.t. classification.

Vaccinium myrtillus was noted to intergrade with *V. scoparium* and to a lesser extent with *V. globulare* in the northernmost portion of the study area. Virtually all of this material was treated as *V. scoparium* because of its broomlike branching habit, small leaf size, and occupancy of habitats similar to those characterized elsewhere by *V. scoparium.*

Arnica cordifolia and *A. latifolia* are a confusing pair, but *A. cordifolia* usually occupies warmer, drier sites and has leaves of a deep, intense green, with distinct petioles and the pairs progressively reduced from the basal pair upward. *Arnica latifolia* occurs at higher elevations and has lighter, lettuce-green leaves, of which the middle pair on flowering stems is sessile and larger than those above or below. Confident separation of the two taxa is possible only by examination of mature achenes.

At the upper elevational limits of *Tsuga heterophylla,* some of its characteristics, particularly branching habit and leaf arrangements, intergrade with those of *T. mertensiana* (even where *T. mertensiana* is not present at higher elevations!). The two *Tsuga* species are most easily separated on the basis of ovulate cone size; those of *T. merten-*

siana are generally longer than 1 inch (>2.5 cm), while those of *T. heterophylla* are 1 inch or less (≤2.5 cm).

SYNECOLOGICAL PERSPECTIVE AND TERMINOLOGY

Habitat Type: Definition and Interpretation

Daubenmire (1968a) defined habitat type as all those land areas potentially capable of supporting similar plant communities at climax. Although this "climax" is theoretical and seldom develops (because of recurring disturbance), the trend toward climax can be identified rather readily in the field from an examination of stand structure. Thus h.t.'s are based on potential climax vegetation. The climax plant community, because it is the relatively stable concluding stage of plant succession and in dynamic equilibrium with its macroclimate, is the most meaningful index of the environmental factors affecting vegetation. A habitat type represents a relatively narrow span of the environmental spectrum. The vast majority of land area included in any one h.t. is recovering from disturbance and thus occupied by seral plant communities; however, the ultimate product of vegetative succession anywhere within the habitat type will always be similar climax communities. Thus the habitat type system is to some (Pfister and Arno 1980; Steele and others 1981) a site or land classification system that employs the plant community (projected to its potential climax state) as an integrated bioassay of environmental factors as they affect species reproduction and competitive effects. Others (Hall 1980; Mueller-Dombois 1964) specify that to function as a site or land classification system, habitat types should be more narrowly defined; they include landscape features, productivity, and other management-oriented variables in habitat type definitions.

Habitat types are logically named for the potential climax community type or plant association (Daubenmire and Daubenmire 1968); for example *Abies lasiocarpa/Xerophyllum tenax*. The classification's series level is denoted by the first portion of the name identifying the potential climax tree species, usually the most shade-tolerant tree adapted to the site. The second part of the name refers to a dominant **or** indicator undergrowth species of the plant association. Presence of a third species name designates the phase level, such as *Abies lasiocarpa/Xerophyllum tenax-Luzula hitchcockii* (see Habitat Type Classification section for an explanation of h.t. abbreviations). Phases represent a difference in vegetation dominance in a third layer, a broad transition between two adjacent habitat types, or minor floristic variation within an h.t. These differences are more specifically referred to as facies, subassociations, and variants by Crawford and Johnson (1985).

Three misconceptions stemming from the use of plant association names are that: (1) an abundance of climax vegetation is present in the current landscape; (2) we should manage the resource to promote climax vegetation; and (3) to apply this classification system requires climax vegetation. The converse is actually the case in the first two instances: (1) A very high percentage of our forested landscape reflects some degree of disturbance, resulting in the preponderance of seral stages. (2) Management strategies usually favor seral species, regardless of the h.t. Regarding the third misconception, comparing the relative reproductive success of the present tree species with known successional patterns and scrutinizing the current undergrowth vegetation generally permit habitat type identification. Largely as a consequence of their temporally compressed life histories, succession appears to be more rapid for the undergrowth species than for the tree layer. The undergrowth becomes compositionally relatively stable concurrent with tree canopy closure. Where stands have been severely disturbed, are in very early seral stages, or have closed canopies, with depauperate understory vegetation comparison of the stand with adjacent stands of later seral stages having comparable site factors permits confident h.t. identification.

Attributes of habitat type classifications useful to land and resource managers are: (1) they provide a permanent and ecologically based system of land stratification referenced to vegetation potential (Daubenmire 1976); (2) they furnish a vegetational classification system for mature to near-climax forest communities; (3) they serve as a system in which succession modeling, the next logical area of investigation for increasing management effectiveness, can proceed; and (4) from units of land within the same type can be expected generally similar successional responses to management treatments or natural perturbations.

Habitat Type Versus Continuum Philosophy

Plant community ecologists have for many years heatedly debated the interpretation of plant community organization. Numerous "schools" and philosophies have originated, but the debate can be generalized to two opposing views: (1) typal community advocates maintain that plant succession leads to relatively distinct climax vegetation types and these types repeat, insofar as floristic vagaries permit, across the landscape (Daubenmire 1966); (2) continuum advocates contend that at climax, vegetation, like climate, varies continuously over the landscape (Cottam and McIntosh 1966; Vogl 1966; Whitaker 1967). While ecologists still debate this question, more pertinent questions for land managers are "what constitutes a type?" and "what criteria should be used for establishing types?" (Hall 1980).

Some Synecological Relationships

We have subscribed to the terminology and polyclimax concepts of Tansley (1935) when describing the relationship of a habitat type to environmental variables. Climax communities are classified and named according to the predominant factor responsible for determining their character. Thus a **climatic climax** characterizes "normal" topography and soils and is not dependent upon fire or animal disturbance to maintain its character; it reflects the prevailing macroclimate of an area. An **edaphic climax** is indicated where peculiarities of the substrate are sufficiently influential to produce a vegetation type differing from the climatic climax. **Topographic climaxes** are characterized by distinctive microclimates produced by

aspect effects, peculiarities of air drainage, or precipitation redistribution. **Topoedaphic climaxes** reflect the combined effects of soils and topography, causing a shift away from the prevailing climatic climax.

Some habitat types occur exclusively as one type of climax, but most can occur in any polyclimax category due to factor compensation. Factor compensation is responsible, for instance, for the *Pseudotsuga menziesii/Physocarpus malvaceus* h.t. shifting from warm, dry, south-facing slopes in northern Idaho to generally steep north slopes east of the Continental Divide in Montana. Where this h.t. occurs in the western part of its range, precipitation is relatively high; in the lower precipitation eastern part of its range, it occurs on north aspects where sufficient environmental moisture is retained. Factor compensation also explains why, within a localized area, a given type will gradually shift from, say, steep north-facing slopes at low elevations to warmer southerly aspects with increasing elevation. As Steele and others (1981) have noted, climatic climaxes are scarce in Idaho; vegetation distribution is strongly determined by topographic features (slope aspect, inclination, and position) or edaphic features such as layers of volcanic ash and glacial drift.

Factor compensation, combined with the natural variability of biological systems (either at the organismal or community level), explain why individual habitat types occur over what may appear to be a broad range of environments. Individual stands may exhibit some modal (average, commonly observed) characteristics and some attributes transitional to other types, especially where major climatic, edaphic, or topographic types grade from one to another. The natural temporal and spatial variation inherent in vegetation and environment dictates that a classification system address transitional types. The two extreme solutions to partitioning variation in vegetation are (1) a relatively simple system with broadly defined types and narrow ecotones and (2) narrowly defined types with either unclassified broad ecotones or numerous types. We have written the keys in specific terms that allow for only narrow ecotones between h.t.'s and facilitate field identification; with this approach more of the land is identifiable to habitat type for practical resource management. Written type descriptions emphasize the modal conditions, with extremes of the type noted. Our intention was to achieve a balance among numbers of classified units, application to field conditions, and natural variation within types.

Habitat types have geographic distributions and variation that follow regional patterns of floristics, climate, and topography. They occupy various soils and topographic positions near their distributional centers, but near their limits of distribution they are more confined to particular topographic positions and substrates. The areal extent of an h.t. thus varies geographically, although the relative position in vegetation-soil sequences remains constant.

A type occupying a broad area between two other types in one geographic area may be recognizable as only a narrow ecotonal situation in other geographic areas. Our h.t. descriptions attempt to generalize about a type's area of occurrence, but because our travels were limited to a small percentage of the total area represented by the classification, the presence of a particular type in a given area will not have been noted—**do not** depend on cited areas of occurrence as an objective criterion of whether you have correctly keyed a particular stand.

Scale of mapping and type of management action will influence how these transitional areas (ecotones) are interpreted and displayed. Ecotones and "hybrid" stands may cause some frustration, but can be mapped as intergrades ("a mixture of h.t. A and h.t. B"), referenced to adjacent or ecologically similar types, and managed accordingly.

PHYSICAL SETTING

Climate and Microclimate

The dominant climatic influence in northern Idaho is the prevailing westerlies which carry maritime air masses from the northern Pacific Ocean across the Northern Rockies during the winter and spring, and continue eastward but in increasingly modified form. This "inland maritime" regime occurs from British Columbia's Selkirk Range, southward 150 to 200 mi (250 to 330 km) to the northern Clearwater National Forest, its intensity gradationally decreasing north to south across the study area. A gradient of decreasing maritime influence also exists from west to east because successive mountain ridges bring about the depletion of moisture within the air masses (they also buffer the intensity of Pacific storm systems in summer). Concomitant with this climatic pattern are gradients in the flora composition and vegetation types of this region (Daubenmire and Daubenmire 1968). During winter and spring, the "inland maritime" regime is characterized by precipitation occurring as prolonged gentle rains, deep snow accumulations at higher elevations, with abundant cloudiness, fog, and high humidity. Winter temperatures are 15 to 25 °F (8 to 14 °C) warmer than continental or East Coast locations of comparable latitude, except during chinook periods, when locations east of the Continental Divide reach 50 to 60 °F (10 to 16 °C). Temperatures on the east side of the Northern Rocky Mountains are much more extreme at both ends of the scale. The mild, moderate winters are in part responsible for the productive forests of northern Idaho (Franklin and Waring 1980).

Summers (specifically July and August) are very dry (usually <1 inch [2.5 cm] precipitation per month; see appendix E) as a consequence of West Coast subtropical high pressure system shifting northward in late June causing the prevailing westerlies to carry dry subsiding air across northern Idaho (Ross and Savage 1967). Most summer precipitation is associated with convectional storms; however, there are occasional "dry" thunderstorms, which constitute a severe fire hazard when coupled with dry fuels.

Elevation is a major influence on climate and consequently on vegetation patterns. The lowest elevations on the western periphery are the warmest, driest locations within the core area; they are on the steppe-forest ecotone (see appendix E, Grangeville). The shifts from one forest type to another are controlled at lower elevations primarily by moisture, and at upper elevations principally by temperature (Daubenmire 1956). Except for a few of the highest peaks, the highest elevations of northern Idaho are not above climatic timberlines and support only traces of alpine tundra communities (Layser 1980).

Generally, precipitation increases with elevation but temperature decreases. If these were the only factors governing local vegetation distribution, we would expect vegetation zones to be serial and parallel, arranged by elevation. But such zonation is patently not the pattern in rugged mountainous terrain. Daubenmire (1980) has provided a dramatic, didactic illustration (fig. 2) of how topographic features may produce distinct meso-microclimates and complicated vegetation patterns. In figure 2, two zonal patterns are delineated. Studying only the fully exposed south-slope interfluves (area between adjacent streams flowing in the same direction), one can identify an east-west series of vegetational (elevational) zones that are decidedly tilted, with ends toward the steppe (west) occurring at relatively high elevations. This pattern is explained by assuming that the lower temperatures of increasing elevations compensate for the decreased precipitation as one nears the semiarid steppe.

Oriented somewhat perpendicularly to the relatively horizontal system of the other vegetation types, the islands of relatively mesophytic (moist) *Thuja plicata/Clintonia uniflora* h.t. that occur in the deep valleys of the south slope constitute a second system of zones. Because these draws are deeply incised and south-facing, sunlight reaches the valley bottoms only at midday and the valley-dependent vegetation is relatively mesophytic. Starting at the ridge's western extremity, the vegetation of the spindle-shaped islands becomes increasingly more diverse, more mesophytic, and more extensive to the east. The most mesophytic types (some more mesophytic at the eastern extreme and bottoms than conveyed in diagram) are located deepest in the valley, the center of a concentric pattern.

In ascending the drainages from the steppe, one encounters progressively more mesophytic vegetation types, but somewhat above the elevational middle the order is reversed. The drought-mitigating effect of lowering air temperatures cannot compensate for the combined effects of increasing exposure and insolation coupled with the blow-over effect on precipitation (Daubenmire 1980, 1981).

Where the main ridge crest dips and projects a lateral spur immediately to the west, strips of the mesophytic types extend up to and across the crest, becoming continuous with a comparable mesophytic forest on the north face. Valley systems change from islandlike to peninsula-like with increasing distance from the range's west end. The island effect is due to protection from desiccating winds; the peninsula, to increasing orographically stimulated precipitation.

From *Thuja* forests to steppe, every locally important vegetation type can be found between 3,300 and 4,900 ft (1,000 and 1,500 m) on this south slope of the Palouse Range. This vegetation mosaic, not atypical for mountainous terrain, could be made considerably more complex if a substrate discontinuity were superimposed on the existing environmental variation.

Physiography and Geology

Northern Idaho is included in two geological provinces. The major portion of the area is within the Northern Rocky Mountains Province; the western fringe is within the Columbia Intermontane Province (Thornbury 1965). The Columbia Intermontane Province extends from just southwest of Coeur d'Alene southward toward Boise. Along this front it interfingers with the Northern Rocky Mountains Province.

The Columbia Intermontane Province is underlain by Columbia River basalts, but these basalts are not generally exposed, nor do they constitute the dominant weathering material for soil formation because of a thick (to 40 ft [12 m]) wind-deposited mantle of loess. This loesal material has a maximum thickness to the north (Palouse Hills Section). It also extends into the Northern Rockies where the greatest accumulations are found on lee slopes (northeast exposures) mixed with volcanic ash; and to the south and

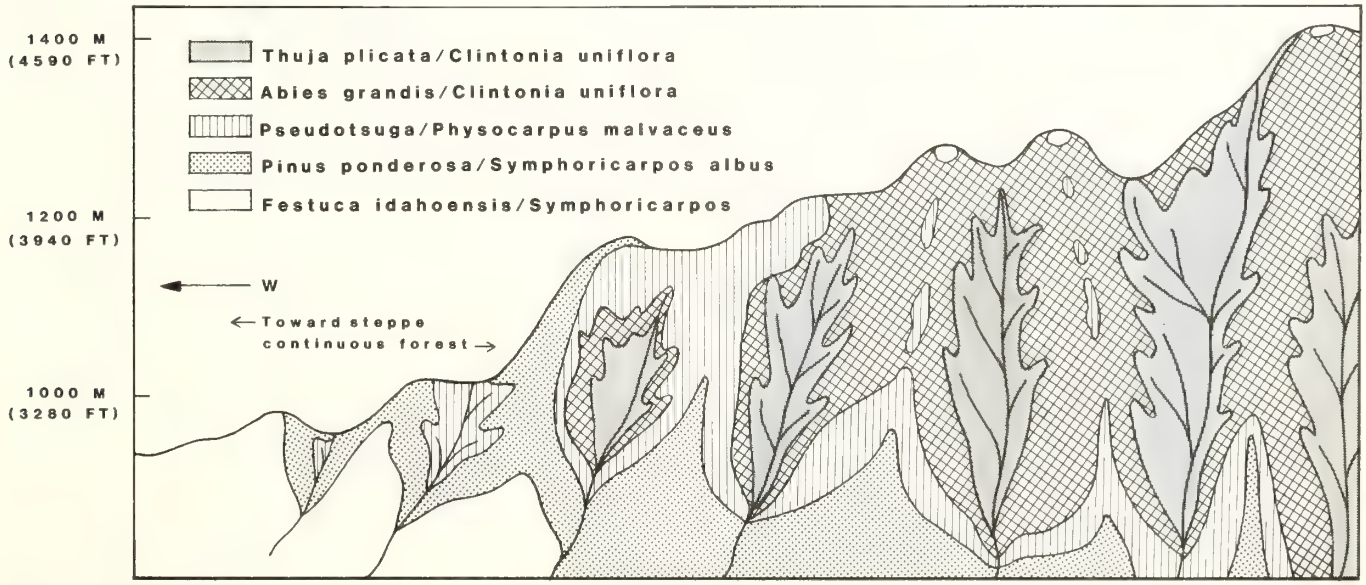


Figure 2—Diagrammatic representation of habitat type—topography relationships on the south face of the Palouse Range (after Daubenmire 1980).

east of Grangeville it grades to a thin covering. Soils derived from basalt-loess constitute very productive substrates for tree growth; but this area, excepting overly steep slopes or shallow soils, has been largely cleared and put into cropland.

The most extensive exposure of weathered basalt and greatest vertical relief (1,500 to 9,000 ft [460 to 2,745 m]) are exhibited in the Seven Devils Mountains area (Wallowa-Seven Devils Section), and Hells Canyon, which forms the western border of the study area (fig. 1). A great variety of rock types are exposed in this relief, but the soils are generally shallow and despite the dominance of a weak "inland maritime" climatic regime range communities are prevalent on warm exposures at low to midelevations.

The Northern Rocky Mountains Province includes four mountain groups with a great diversity of geology, structure, and topography. Two of these groups occur in the core area. The Central Idaho Range (Thornbury 1965) extending from north of the Snake River Plains to Lake Pend Oreille is such a broad, undifferentiated mass, so lacking lineation that the term "range" is only loosely applied. Only the Bitterroot Range on the eastern margin forms a linear northwest-southeast trending chain of high peaks (a few exceeding 9,000 ft [2,745 m]). The boundaries between the mountain "ranges" of central Idaho (including Clearwater, Coeur d'Alene, and Bitterroot in our area) are poorly defined. The relative lithologic homogeneity imposed by both the Precambrian Belt Supergroup metasediments and Idaho Batholith granitics (quartz monzonites and granodiorites) is reflected in the sprawling mountains, dendritic drainages, narrow V-shaped valleys, scant topographical lineation, and accordant ridges.

Border Zone rocks—Belt Series metasediments altered by batholith intrusion—occurring north and west of the Idaho Batholith, primarily on the northern Nez Perce and Clearwater NF's, are well weathered and produce deep, massively unstable soils. Granitic-derived soils prevalent on the Nez Perce NF are generally thin and highly erodable (Arnold 1975).

Tertiary and quaternary glacial drift is extensive in the Elk City Basin and occurs sporadically to the north, where large deposits are again present in the Coeur d'Alene-Rathdrum Prairie vicinity.

Extending north from the Clark Fork drainage of the Columbia River and west from the Front Range in Montana to the Selkirk Mountains on the Idaho-Washington border are a number of linear northwest-to-southeast trending, imbricately thrust-faulted ranges, where the surface exposures are primarily Belt Supergroup argillites and quartzites (fig. 1). These ranges (few in northern Idaho exceed 7,000 ft [2,140 m]), and associated valleys were twice overridden by the continental glacier. The preglacial loess was scoured away leaving a coarse and less fertile substrate on the uplands and U-shaped valleys floored with glacial drift. The Purcell Trench, stretching from Coeur d'Alene into Canada, is the largest example (in our area) of a broad-floored basin associated with the glacial erosion-deposition of a major intermontane ice lobe (Thornbury 1965); the Purcell Trench also has major lacustrine deposits from glacial Lake Kootenai. The mosaic pattern in the particle size composition of these deposits (especially where mixed with volcanic ash eroded from the highlands) produces a corresponding complex of plant communities.

Postglacial time has seen the deposition of eolian materials, especially volcanic ash (predominantly Mount Mazama [Nimlos and Zuring 1982]), which has been concentrated (locally exceeding a meter in depth) on north to northeast exposures. The differential deposition of these materials, combined with precipitation redistribution to northerly exposures by prevailing southwest winds, further accentuates the contrast in north-south slope plant communities.

SUCCESSIONAL STATUS

Fire History

Recognition and documentation of the importance of natural (lightning-caused) fires for the perpetuation of natural forest ecosystems and landscape diversity in the Northern Rocky Mountains is steadily accumulating (Arno 1980; Habeck and Mutch 1973; Romme 1982; Wellner 1970a). Incidence of fire in these ecosystems is practically a certainty within 400 to 500 years from stand initiation (Daubenmire and Daubenmire 1968), but natural fire-free intervals are considerably shorter. The studies of Barrett and Arno (1982) emphasize the extensive impact that burning (planned or otherwise) by Native Americans has had on maintaining stand structure and composition. Other human-caused fires were set by prospectors to expose mineral outcrops (Space 1964) and by settlers for range improvement.

Virtually every stand we sampled had some indication of past fire: even-aged size-class structure of seral species, charred material on the ground, burned-out stumps and snags, charcoal in the soil profile, and fire-scarred boles (usually the exception—evidence indicated a high proportion of stand-replacing fires). Where fire evidence was not immediately obvious, soil probing could almost invariably produce charcoal traces. Only unproductive, high-elevation sites or wet sites occasionally lacked fire evidence.

Thus it is not surprising that the most abundant tree species in northern Idaho are seral ones adapted to a landscape periodically disturbed by fire. Mature *Larix occidentalis*, *Pinus ponderosa*, and *Pseudotsuga menziesii* have thick, corky, fire-resistant bark. The previously cited species and *Pinus monticola* have light and/or winged seed, or as is the case with *Pinus contorta*, serotinous cones, adaptations for early arrival on burned sites. Their growth patterns are characterized by rapid initial height growth favoring them over their shade-tolerant competitors. Even-aged stand structure that results following extensive stand-replacing fires (for example, 1910 burns) is circumstantial evidence that a considerable amount of viable seed survives these catastrophic fires. The distances from the nearest seed wall to the center of burned areas virtually preclude effective seed dispersal.

Arno's (1980) recent synopsis of fire history in the Northern Rockies and other publications (Arno 1976; Davis and others 1980; Wellner 1970a) indicate that the fire-free interval ("fire-return interval" in other studies) can be related to climax tree series and habitat type. On a

local scale, incidence of fire (predominantly surface fire) decreases with decreasing moisture stress, from mean fire-free intervals of 6 years on *Pinus ponderosa-Pseudotsuga menziesii*/bunchgrass types to 40+ years on subalpine h.t.'s (Arno and Petersen 1983).

Surface fires also occur in the *Thuja-Tsuga* forests of northern Idaho, but with much-reduced frequency compared to northwestern Montana or the Nez Perce NF, where reconnaissance data show 40 to 80 percent of the stands in *Thuja* h.t.'s experience ground fire. Studies on small subunits (150 to 300 acres [60 to 120 ha]) of the Priest Lake Ranger District, Kaniksu NF (Arno and Davis 1980) indicate only one or two significant fires per century can be expected on upland *Thuja-Tsuga* h.t.'s. Wet-site *Thuja-Tsuga* subunits experience only very limited lightning-strike spot fires; average stand-replacing fire intervals may exceed 500 years. The *Abies lasiocarpa* h.t.'s associated with the *Tsuga-Thuja* zone have much longer fire-free intervals (to 250+ years) and reduced burn sizes (<10 acres [4 ha] [Arno and Davis 1980] compared to ABLA series h.t.'s on the Lolo and Bitterroot NF's [beyond the *Tsuga-Thuja* zone] [Arno and Petersen 1983; Davis and others 1980]). Arno and Davis (1980) have speculated on management implications associated with the types and frequencies of fire as they interact with h.t.'s, seral species, and site properties on *Thuja-Tsuga* zone forests.

The high productivities of *Thuja-Tsuga* forests reflect their mesic environments; however, every few years an extreme summer drought occurs. Drought, combined with drying winds, vastly increases the probability of large, stand-replacing fires. The destructive 56,000-acre (22,700-ha) Sundance Fire (Kaniksu NF) of 1967 (Anderson 1968) was the most recent example of the massive crown fires that collectively have burned millions of acres. Other extensive fires occurred in 1934, 1926, 1919, 1889, and most notably 1910 (990,000 acres [400,000 ha] burned on the Clearwater and Nez Perce NF's alone [Barrows 1952]). The U.S. Forest Service Northern Region (R-1) experiences about three times as many lightning fires as the Intermountain Region (R-4), and the western zone (R-1, west of Continental Divide) records six times as many lightning fires as the eastern zone (Barrows 1952). The Clearwater and Nez Perce NF's are clearly the regional focus of lightning fires, both in terms of the average number of fires per million acres (114 and 67, respectively, computed on period 1931-45) and average annual acreage burned per million acres (5,670 and 7,580, respectively). The average acreage burned per million acres for these forests is two to 10 times greater than on contiguous forest lands.

Wellner (1970a) describes how the accumulation of dead, fallen fuels from previous fires may set the stage for massive and successive fires, the eventual outcome being retarded establishment of forest because of seed source elimination and long-persisting shrub and forb fields (dominated by *Salix scouleriana*, *Amelanchier alnifolia*, *Ceanothus* spp., *Acer glabrum*, *Prunus* spp., *Physocarpus malvaceus*, *Holodiscus discolor*, *Pteridium aquilinum*, and *Rudbeckia occidentalis*). On the Clearwater NF (centered on Cook Mountain area) we find the most extensive reburns and shrubfields in the Northern Rockies. Barrett (1982) has speculated on the combination of factors responsible for these conflagrations: (1) less summer rainfall than northward in the panhandle, yet still enough moisture for rapid fuel buildup; (2) local topography favoring the drying influence of prevailing westerlies on mid and upper slope forests; (3) high lightning frequency.

Succession modeling (Arno and others 1985) in four extensive habitat types of western Montana (important h.t.'s also in northern Idaho) has documented that the intensity of burn, along with preburn vegetational composition and h.t., are important variables in predicting response to wildfire. The results of Arno and others (1985) have important implications about managing for particular species through specific treatments. In many cases, successional responses to combinations of logging and site preparation will mimic the vegetational responses to wildfire. Fire history studies in combination with succession modeling of vegetation, fuels, and flammability have great potential for ecological understanding of the natural role of wildfire, how fire may be best managed, and the use of prescribed fire as a tool (prescription) to achieve land management objectives. (See Logging History section for additional citations regarding succession models.)

Logging History

Centers of mining activity were the first areas to be heavily logged. Timber was used for construction, mine supports, and fuel for stamp mills and smelters. Cutting for ties was extensive along railroad lines. Early in the century the most fertile and accessible valleys and adjacent gentle slopes were cleared for agriculture, and upslope stands were used for fuel and building materials. Loggers soon gained access to more remote stands of valuable timber and floated huge log-booms to downstream mills on the major watercourses of the area. Records of these early activities are preserved in springboard cuts on large rot-resistant *Thuja plicata* stumps. Some areas with these relicts have produced a second cutting and are well on their way to a third.

The biggest spur to increased harvesting was the booming wartime (World War II) and postwar economy. For instance, on the Clearwater NF the largest cut prior to 1946 was 18.0 million board ft (MM bd ft), but the annual cut jumped to 116.3 MM bd ft by 1959, and since has dropped below 100 MM bd ft only once; similar increases in harvested volume occurred on other forests in the region. With continued pressure to harvest old-growth stands and the introduction of aerial logging techniques making stands accessible where harvesting was once deemed impractical, it appeared that only the most remote (or unproductive) stands would remain undisturbed. But the Research Natural Areas (RNA) program is preserving primarily old-growth areas representative of formerly extensive types. Also, National Forests are setting aside a certain percentage of their remaining old-growth stands, recognizing that certain wildlife species are dependent upon this structural state.

Succession models have also been constructed with various cutting practices and site treatments constituting the disturbance types (a major prediction variable). Some models are data intensive, geographically restricted, and

treat all lifeforms (for example Arno and others 1985 in western Montana). Others are deterministic, of broad geographic application, but emphasize the response of tree and shrub parameters (Laurson 1984; Moeur 1985; Scharosch 1984). Moeur's (1985) model, COVER, an extension of version 5.0 of the Strand Prognosis Model (Wykoff and others 1982; Wykoff 1985) incorporates the databases of Laurson (1984), Scharosch (1984), and Ferguson and others (1986) making the model applicable to the Inland Northwest and Northern Rocky Mountains.

THE HABITAT TYPE CLASSIFICATION

We have defined 83 forest habitat types and phases for northern Idaho. This number represents more than a threefold increase over the Daubenmires' 22 taxonomic units and is a more detailed representation of the environmental diversity of the study area. To conserve space, the term habitat type is abbreviated h.t. (h.t.'s plural) as are the h.t. names. The first two letters of the genus and species epitaph are combined and capitalized for the appropriate overstory (series level) and undergrowth species (habitat type and phase levels) to generate the abbreviation of each taxonomic unit; for example *Abies lasiocarpa/ Clintonia uniflora* becomes ABLA/CLUN. For convenient reference the complete classification by scientific, abbreviated, and common names is listed in table 1. To avoid confusion common names are not used in the text. Foresters and biologists have readily adopted the scientific name abbreviations for accurate and concise referencing in both written and verbal communication.

The classification follows the order:

1. Key to the habitat types (fig. 3). **A careful reading of the instructions and definitions used in the key is essential.** Identification proceeds from climax series, to habitat type, and finally to phase (where indicated). These steps should not be circumvented until the user has become thoroughly familiar with the classification. A field guide to common forest plants of northern Idaho is specifically designed to aid in indicator species identification (Patterson and others 1985).

2. Series description. Some h.t. characteristics are summarized at the series level, avoiding repetition at the h.t. level.

3. Habitat type description. The h.t. is characterized in terms of extent, environmental variables, geographic range, vegetation, phases, soils, productivity, and management implications. All designations regarding slope aspect proceed in a clockwise direction from north.

   a. The order of series and h.t. identification tends to follow a moisture gradient, from wettest to driest.

   b. When considering lower elevation environments, progressing through the key leads generally to drier h.t.'s; at upper elevations, progressing through the key leads to increasingly colder h.t.'s.

   c. Species with the greatest importance as indicators (or narrowest ecological amplitude) tend to appear first in the key.

   d. When types from different geographic areas are merged into one key, this order may deviate. Not all series or types occur in any one region, as is revealed in a comparison of figures 4 and 5 showing generalized series-level zonations for northernmost Idaho and the Nez Perce NF (southern portion of northern Idaho). In northernmost Idaho only exceptionally dry (excessively drained) sites are capable of supporting the *Pinus ponderosa* or *Pseudotsuga menziesii* series and the *Tsuga heterophylla* series is areally extensive; conversely, on the Nez Perce NF the *T. heterophylla* series is nonexistent and the *P. menziesii* series is well represented.

Table 1—Forest habitat types and phases by series for northern Idaho; order of h.t.'s follows their position in the key; see key for page number of written descriptions

ADP code[1]	Abbreviation	Scientific name	Common name
502	TSHE	***TSUGA HETEROPHYLLA* SERIES**	
565	TSHE/GYDR	*T. heterophylla/Gymnocarpium dryopteris* h.t.	western hemlock/oak-fern
575	TSHE/ASCA	*T. heterophylla/Asarum caudatum* h.t.	western hemlock/wild ginger
576	-ARNU	*-Aralia nudicaulis* phase	-wild sarsaparilla
577	-MEFE	*-Menziesia ferruginea* phase	-menziesia
578	-ASCA	*-Asarum caudatum* phase	-wild ginger
570	TSHE/CLUN	*T. heterophylla/Clintonia uniflora* h.t.	western hemlock/queencup beadlily
572	-ARNU	*-Aralia nudicaulis* phase	-wild sarsaparilla
573	-MEFE	*-Menziesia ferruginea* phase	-menziesia
574	-XETE	*-Xerophyllum tenax* phase	-beargrass
571	-CLUN	*-Clintonia uniflora* phase	-queencup beadlily
579	TSHE/MEFE[2]	*T. heterophylla/Menziesia ferruginea* h.t.	western hemlock/menziesia
501	THPL	***THUJA PLICATA* SERIES**	
550	THPL/OPHO	*T. plicata/Oplopanax horridum* h.t.	western redcedar/devil's club
540	THPL/ATFI	*T. plicata/Athyrium filix-femina* h.t.	western redcedar/lady-fern
541	-ADPE	*-Adiantum pedatum* phase	-maidenhair fern
542	-ATFI	*-Athyrium filix-femina* phase	-lady-fern
560	THPL/ADPE	*T. plicata/Adiantum pedatum* h.t.	western redcedar/maidenhair fern
555	THPL/GYDR	*T. plicata/Gymnocarpium dryopteris* h.t.	western redcedar/oak-fern
545	THPL/ASCA	*T. plicata/Asarum caudatum* h.t.	western redcedar/wild ginger
547	-MEFE	*-Menziesia ferruginea* phase	-menziesia
548	-TABR	*-Taxus brevifolia* phase	-Pacific yew
546	-ASCA	*-Asarum caudatum* phase	-wild ginger
530	THPL/CLUN	*T. plicata/Clintonia uniflora* h.t.	western redcedar/queencup beadlily
533	-MEFE	*-Menziesia ferruginea* phase	-menziesia
535	-TABR	*-Taxus brevifolia* phase	-Pacific yew
534	-XETE	*-Xerophyllum tenax* phase	-beargrass
531	-CLUN	*-Clintonia uniflora* phase	-queencup beadlily
701	TSME	***TSUGA MERTENSIANA* SERIES**	
675	TSME/STAM	*T. mertensiana/Streptopus amplexifolius* h.t.	mountain hemlock/twisted-stalk
676	-LUHI	*-Luzula hitchcockii* phase	-smooth woodrush
677	-MEFE	*-Menziesia ferruginea* phase	-menziesia
685	TSME/CLUN	*T. mertensiana/Clintonia uniflora* h.t.	mountain hemlock/queencup beadlily
686	-MEFE	*-Menziesia ferruginea* phase	-menziesia
687	-XETE	*-Xerophyllum tenax* phase	-beargrass
680	TSME/MEFE	*T. mertensiana/Menziesia ferruginea* h.t.	mountain hemlock/menziesia
681	-LUHI	*-Luzula hitchcockii* phase	-smooth woodrush
682	-XETE	*-Xerophyllum tenax* phase	-beargrass
710	TSME/XETE	*T. mertensiana/Xerophyllum tenax* h.t.	mountain hemlock/beargrass
711	-LUHI	*-Luzula hitchcockii* phase	-smooth woodrush
713	-VASC	*-Vaccinium scoparium* phase	-grouse whortleberry
712	-XETE	*-Xerophyllum tenax* phase	-beargrass
840	TSME/LUHI[2]	*T. mertensiana/Luzula hitchcockii* h.t.	mountain hemlock/smooth woodrush
600	ABLA	***ABIES LASIOCARPA* SERIES**	
650	ABLA/CACA	*A. lasiocarpa/Calamagrostis canadensis* h.t.	subalpine fir/bluejoint
655	-LEGL	*-Ledum glandulosum* phase	-Labrador-tea
654	-VACA[2]	*-Vaccinium caespitosum* phase	-dwarf huckleberry
652	-LICA[2]	*-Ligusticum canbyi* phase	-Canby's ligusticum
651	-CACA	*-Calamagrostis canadensis* phase	-bluejoint
635	ABLA/STAM	*A. lasiocarpa/Streptopus amplexifolius* h.t.	subalpine fir/twisted-stalk
636	-MEFE	*-Menziesia ferruginea* phase	-menziesia
637	-LICA	*-Ligusticum canbyi* phase	-Canby's ligusticum
620	ABLA/CLUN	*A. lasiocarpa/Clintonia uniflora* h.t.	subalpine fir/queencup beadlily
625	-MEFE	*-Menziesia ferruginea* phase	-menziesia
624	-XETE	*-Xerophyllum tenax* phase	-beargrass
621	-CLUN[2]	*-Clintonia uniflora* phase	-queencup beadlily
670	ABLA/MEFE	*A. lasiocarpa/Menziesia ferruginea* h.t.	subalpine fir/menziesia
672	-LUHI	*-Luzula hitchcockii* phase	-smooth woodrush
674	-VASC	*-Vaccinium scoparium* phase	-grouse whortleberry
671	-COOC[2]	*-Coptis occidentalis* phase	-western goldthread
673	-XETE	*-Xerophyllum tenax* phase	-beargrass
640	ABLA/VACA[2]	*A. lasiocarpa/Vaccinium caespitosum* h.t.	subalpine fir/dwarf huckleberry

Table 1 (Con.)

ADP code[1]	Abbreviation	Scientific name	Common name
690	ABLA/XETE	*A. lasiocarpa/Xerophyllum tenax* h.t.	subalpine fir/beargrass
694	-LUHI	-*Luzula hitchcockii* phase	-smooth woodrush
692	-VASC	-*Vaccinium scoparium* phase	-grouse whortleberry
693	-COOC	-*Coptis occidentalis* phase	-western goldthread
691	-VAGL	-*Vaccinium globulare* phase	-blue huckleberry
720	ABLA/VAGL[2]	*A. lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry
750	ABLA/CARU[2]	*A. lasiocarpa/Calamagrostis rubescens* h.t.	subalpine fir/pinegrass
730	ABLA/VASC[2]	*A. lasiocarpa/Vaccinium scoparium* h.t.	subalpine fir/grouse whortleberry
830	ABLA/LUHI[2]	*A. lasiocarpa/Luzula hitchcockii* h.t.	subalpine fir/smooth woodrush
860	LALY-ABLA[2]	*Larix lyallii-Abies lasiocarpa* h.t.'s	alpine larch-subalpine fir
850	PIAL-ABLA[2]	*Pinus albicaulis-Abies lasiocarpa* h.t.'s	whitebark pine-subalpine fir
500	ABGR	***ABIES GRANDIS* SERIES**	
529	ABGR/SETR[2]	*A. grandis/Senecio triangularis* h.t.	grand fir/arrowleaf groundsel
516	ABGR/ASCA	*A. grandis/Asarum caudatum* h.t.	grand fir/wild ginger
518	-MEFE	-*Menziesia ferruginea* phase	-menziesia
519	-TABR	-*Taxus brevifolia* phase	-Pacific yew
517	-ASCA	-*Asarum caudatum* phase	-wild ginger
520	ABGR/CLUN	*A. grandis/Clintonia uniflora* h.t.	grand fir/queencup beadlily
525	-MEFE	-*Menziesia ferruginea* phase	-menziesia
526	-TABR	-*Taxus brevifolia* phase	-Pacific yew
523	-XETE	-*Xerophyllum tenax* phase	-beargrass
524	-PHMA	-*Physocarpus malvaceus* phase	-ninebark
521	-CLUN	-*Clintonia uniflora* phase	-queencup beadlily
590	ABGR/LIBO	*A. grandis/Linnaea borealis* h.t.	grand fir/twinflower
592	-XETE	-*Xerophyllum tenax* phase	-beargrass
591	-LIBO	-*Linnaea borealis* phase	-twinflower
510	ABGR/XETE	*A. grandis/Xerophyllum tenax* h.t.	grand fir/beargrass
511	-COOC	-*Coptis occidentalis* phase	-western goldthread
512	-VAGL	-*Vaccinium globulare* phase	-blue huckleberry
515	ABGR/VAGL[2]	*A. grandis/Vaccinium globulare* h.t.	grand fir/blue huckleberry
506	ABGR/PHMA	*A. grandis/Physocarpus malvaceus* h.t.	grand fir/ninebark
507	-COOC	-*Coptis occidentalis* phase	-western goldthread
508	-PHMA	-*Physocarpus malvaceus* phase	-ninebark
505	ABGR/SPBE	*A. grandis/Spiraea betulifolia* h.t.	grand fir/white spiraea
200	PSME	***PSEUDOTSUGA MENZIESII* SERIES**	
260	PSME/PHMA	*P. menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark
263	-SMST	-*Smilacina stellata* phase	-starry Solomon-plume
261	-PHMA	-*Physocarpus malvaceus* phase	-ninebark
250	PSME/VACA	*P. menziesii/Vaccinium caespitosum* h.t.	Douglas-fir/dwarf huckleberry
280	PSME/VAGL[2]	*P. menziesii/Vaccinium globulare* h.t.	Douglas-fir/blue huckleberry
310	PSME/SYAL[2]	*P. menziesii/Symphoricarpos albus* h.t.	Douglas-fir/common snowberry
340	PSME/SPBE[2]	*P. menziesii/Spiraea betulifolia* h.t.	Douglas-fir/white spiraea
320	PSME/CARU	*P. menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass
322	-ARUV	-*Arctostaphylos uva-ursi* phase	-kinnikinnick
323	-CARU	-*Calamagrostis rubescens* phase	-pinegrass
330	PSME/CAGE[2]	*P. menziesii/Carex geyeri* h.t.	Douglas-fir/elk sedge
220	PSME/FEID[2]	*P. menziesii/Festuca idahoensis* h.t.	Douglas-fir/Idaho fescue
210	PSME/AGSP[2]	*P. menziesii/Agropyron spicatum* h.t.	Douglas-fir/bluebunch wheatgrass
900	PICO	***PINUS CONTORTA* SERIES**	
920	PICO/VACA[2]	*P. contorta/Vaccinium caespitosum* c.t.	lodgepole pine/dwarf huckleberry
925	PICO/XETE[2]	*P. contorta/Xerophyllum tenax* c.t.	lodgepole pine/beargrass
940	PICO/VASC[2]	*P. contorta/Vaccinium scoparium* h.t.	lodgepole pine/grouse whortleberry
100	PIPO	***PINUS PONDEROSA* SERIES**	
190	PIPO/PHMA	*P. ponderosa/Physocarpus malvaceus* h.t.	ponderosa pine/ninebark
170	PIPO/SYAL	*P. ponderosa/Symphoricarpos albus* h.t.	ponderosa pine/common snowberry
140	PIPO/FEID[2]	*P. ponderosa/Festuca idahoensis* h.t.	ponderosa pine/Idaho fescue
130	PIPO/AGSP[2]	*P. ponderosa/Agropyron spicatum* h.t.	ponderosa pine/bluebunch wheatgrass

[1]Automatic data processing code for National Forest System use.
[2]Incidental habitat type, phase, or community type in northern Idaho; eliminated from some other tables and appendixes.

READ THESE INSTRUCTIONS BEFORE USING KEYS!

1. **NOTE**: The key is **NOT** the classification! Validate your selection by comparing the site with the written type description and coverage-constancy tables (appendix C). Refer to the northern Idaho field guide (Patterson and others 1985) that is specifically designed to aid in identification of forest h.t. indicator species.

2. This key is most appropriately applied to stands that are at least at a sapling-pole successional stage. If a severely disturbed community or early seral conditions are encountered, habitat type is best determined by extrapolating from the nearest relatively undisturbed, mature stand with similar site conditions (slope, aspect, elevation, and soils).

3. The plot being classified must be representative of the stand as a whole. If not, and you are not constrained by other considerations, relocate the plot. Plant ecologists consider environmental and/or vegetation homogeneity as primary requisites for plot selection. Stand examination procedures (for example, those employed by the Northern Region, Forest Service) require a systematic plot location within sometimes environmentally heterogeneous stands. If plot relocation is not an acceptable procedure, record the predominant habitat type for the site being classified and note inclusions of other h.t.'s.

4. Accurately identify and record canopy coverages for **all** indicator species using field form (appendix G). Canopy coverage terms for use in the key and written descriptions are diagramed below:

   Depauperate: unusually sparse undergrowth conditions resulting from dense shading or thick duff require the adjustment of canopy coverage values in the key to the next lower class (for instance, "well represented" becomes "common"), or extrapolation from the nearest nondepauperate condition occurring on a comparable site.

   "Present" as applied to all species requires at least 10 individuals per acre (25/ha), not restricted to microsites. Microsites are small areas that are atypical for the stand, such as remnant ash deposits or windthrow pockets filled with colluvium/alluvium.

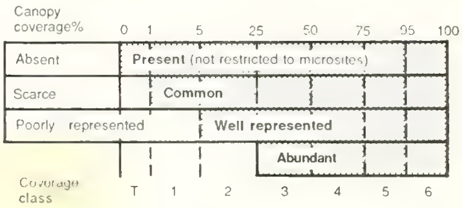
5. Using the SERIES KEY, identify the potential climax tree species. "Successfully reproducing" is considered to be 10 trees per acre (25 trees/ha). NOTE: Extensive, repeated burns have eliminated climax tree seed sources for several square miles in numerous areas; in the most severe cases extensive shrubfields (lacking even seral tree species) have developed. If a site has 10 or more stumps (snags per acre) (25/ha) of a species more shade tolerant than the current tree populations, classify the site to the series indicated by the remnant trees. Where expansive shrubfields have developed, a regional model relating series/habitat type—phase occurrence to site parameters is the most practicable solution. NOTE: **not all shrubfield conditions should be extrapolated to a forestal h.t.** Recent findings regarding a long-recognized problem condition, long-persisting, intractable to reforestation shrubfields and bracken fern (*Pteridium aquilinum*) glades occurring in a mosaic with forest communities, have resulted in a modification of previous versions of our classification. (See nearest series level key, couplet 1.)

6. Within the selected series key, determine habitat type by literally following the key. **All** conditions stipulated for each couplet must be satisfied to make the correct choice. The first set of conditions satisfied by site characteristics should generally supply the correct classification. As stipulated in Instruction 1, validate your determination by checking the written description and constancy-coverage tables.

7. PHASE determination is achieved by matching the first appropriate phase description to the stand conditions. Validate your determination per Instruction 1.

8. Always follow the key to the finest level in the hierarchy. Knowledge of phase can be as, or sometimes more, important than habitat type when developing management prescriptions.

9. Some percentage of stands will not key to a defined habitat type or phase. These plots should be coded to the lowest level identifiable in hierarchy and annotated accordingly. Data accumulated on "no fit" conditions will serve for future refinements of the classification. Several habitat types in the key are not described in the text; references are provided.



KEY TO SERIES LEVEL: NORTH IDAHO REFINEMENT
(item or page numbers followed by ADP code number)

1. Habitats where the canopy dominant is *Alnus sinuata* or *Pteridium aquilinum*; no indication of successful tree reproduction or that past tree density was greater than 10 per acre (25/ha), though scattered *Picea engelmannii* (seedling-saplings) may be present; 2
1. Not as above; sites capable of supporting forest, even if savanna-like or currently dominated by shrubfields 3

   2. *Alnus sinuata* dominated shrub/low tree layer; undergrowth is depauperate (five or fewer herbaceous species present) and *Montia cordifolia* well represented (5%) *Alnus sinuata/Montia cordifolia* h.t.
   2. Not as above .... see *Alnus sinuata* communities under OTHER COMMUNITY TYPES (p. 83)

3. Habitats with unstable broken rock substrate usually on steep (>30 degrees) slopes; sparse, poorly developed, and spatially variable undergrowth .... SCREE (p. 83)
3 Habitats with stable substrates and some soil development; undergrowth well developed and spatially somewhat uniform 2

   4. *Tsuga heterophylla* present and reproducing successfully* .... TSUGA HETEROPHYLLA SERIES (item A)
   4. *T. heterophylla* absent, or, if present, not reproducing successfully 3

5. *Thuja plicata* present and reproducing successfully, though success may be considerably less than competing species and often episodic .... THUJA PLICATA SERIES (item B)
5. *T. plicata* absent or not as above 4

   6. *Tsuga mertensiana* present and reproducing successfully .... TSUGA MERTENSIANA SERIES (item c)
   6. *T. mertensiana* absent 5

Figure 3—Key to climax series, habitat types, and phases.

7. *Abies lasiocarpa* present and reproducing more successfully than *Abies grandis* (or other tree species) .... ABIES LASIOCARPA SERIES (item D)
7. Not as above or *A. grandis* reproduction greater than that of *A. lasiocarpa* 6

8. *Abies grandis* or *Taxus brevifolia* present and reproducing successfully .... ABIES GRANDIS SERIES (item E)
8. *A. grandis* and *T. brevifolia* absent or not reproducing successfully 7

9. *Pseudotsuga menziesii* present and reproducing successfully, though perhaps episodically .... PSEUDOTSUGA MENZIESII SERIES (item F)
9. *P. menziesii* absent or not reproducing successfully 8

10. Virtually pure stands of *Pinus contorta* that may or may not be self-reproducing, and little evidence as to climax tree species .... PINUS CONTORTA SERIES (item G)
10. *Pinus ponderosa* present and reproducing, perhaps episodically .... PINUS PONDEROSA SERIES (item H)

A. *Tsuga heterophylla* Series; Key to Habitat Types

1. *Oplopanax horridum* well represented (≥5%) .... THPL/OPLOPANAX HORRIDUM h.t.[1] (p. 27)
1. *O. horridum* poorly represented (<5%) 2

2. *Athyrium filix-femina* well represented (≥5%) or common (≥1%) if in combination with *Senecio triangularis, Trautvetteria caroliniensis, Streptopus amplexifolius*, and/or *Gymnocarpium dryopteris* .... THPL/ATHYRIUM FILIX-FEMINA h.t.[1] (p. 28)
   a. *Adiantum pedatum* well represented (≥5%) .... ADIANTUM PEDATUM phase
   b. *A. pedatum* poorly represented (<5%) .... A. FILIX-FEMINA phase
2. *A. filix-femina* poorly represented (<5%) or not as above 3

3. *Adiantum pedatum* well represented (≥5%) .... THPL/ADIANTUM PEDATUM h.t.[1] (p. 29)
3. *A. pedatum* poorly represented (<5%) 4

4. *Gymnocarpium dryopteris* common (≥1%) .... TSHE/GYMNOCARPIUM DRYOPTERIS h.t. (p. 20
4. *G. dryopteris* scarce (<1%) 5

5. *Asarum caudatum* present or *Viola glabella* common (≥1%), neither restricted to microsites .... TSHE/ASARUM CAUDATUM h.t. (p. 21)
   a. *Aralia nudicaulis* present, not restricted to microsites .... -ARALIA NUDICAULIS phase
   b. *A. nudicaulis* absent, *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
   c. Not as above .... -ASARUM CAUDATUM phase
5. *A. caudatum* absent and *V. glabella* scarce (<1%) 6

6. *Clintonia uniflora* or *Tiarella trifoliata* present, not restricted to microsites .... TSHE/CLINTONIA UNIFLORA h.t. (p. 23)
   a. *Aralia nudicaulis* present, not restricted to microsites .... -ARALIA NUDICAULIS phase
   b. *A. nudicaulis* absent, *Menziesia ferruginea*, or *Vaccinium scoparium* (*V. myrtillus*) or their combined coverages well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
   c. Not as above, *Xerophyllum tenax* well represented (≥5%) .... -XEROPHYLLUM TENAX phase
   d. Not as above .... -CLINTONIA UNIFLORA phase
6. *C. uniflora* and *T. trifoliata* absent 7

7. *Menziesia ferruginea* and/or *Xerophyllum tenax* well represented (≥5%), and/or fewer than 12 undergrowth species present .... TSHE/MENZIESIA FERRUGINEA h.t. (p. 26)
7. Not as above, then
   a. Reevaluate choice of *Tsuga heterophylla* as appropriate series, and
   b. Note that closed canopy of mid- to late successional stages may have exceedingly depauperate undergrowth; in which case, examine the nearest stand with similar site variables, but a canopy structure permitting undergrowth development, and reenter key
   c. After exhausting the above approaches .... TSHE SERIES (p. 19)

[1]See *Thuja plicata* Series narrative for discussion of *Tsuga heterophylla*-dominated stands in these THPL h.t.'s.

B. *Thuja plicata* Series; Key to Habitat Types

1. *Oplopanax horridum* well represented (≥5%) .... THPL/OPLOPANAX HORRIDUM h.t. (p. 27)
1. *O. horridum* poorly represented (<5%) 2

2. *Athyrium filix-femina* well represented (≥5%) or common (≥1%) if in combination with *Senecio triangularis, Trautvetteria caroliniensis, Streptopus amplexifolius*, and/or *Gymnocarpium dryopteris* .... THPL/ATHYRIUM FILIX-FEMINA h.t. (p. 28)
   a. *Adiantum pedatum* well represented (≥5%) .... -ADIANTUM PEDATUM phase
   b. *A. pedatum* poorly represented (<5%) .... -A. FILIX-FEMINA phase
2. *A. filix-femina* poorly represented (<5%) or not as above 3

3. *Adiantum pedatum* well represented (≥5%) .... THPL/ADIANTUM PEDATUM h.t. (p. 29)
3. *A. pedatum* poorly represented (<5%) 4

4. *Gymnocarpium dryopteris* common (≥1%) .... THPL/GYMNOCARPIUM DRYOPTERIS h.t. (p. 31)
4. *G. dryopteris* scarce (<1%) 5

5. *Asarum caudatum* present, not restricted to microsites or *Viola glabella* common (≥1%) .... THPL/ASARUM CAUDATUM h.t. (p. 32)
   a. *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
   b. *M. ferruginea* poorly represented (<5%), *Taxus brevifolia* well represented (≥5%) .... -TAXUS BREVIFOLIA phase
   c. Not as above, T. brevifolia poorly represented (<5%) .... -ASARUM CAUDATUM phase
5. *A. caudatum* absent or restricted to microsites and *V. glabella* scarce (<1%) 6

Figure 3—(con.)

6. *Clintonia uniflora, Tiarella trifoliata,* or *Coptis occidentalis* present, not restricted to microsites ...... THPL/CLINTONIA UNIFLORA h.t. (p. 34)
   a. *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
   b. *M. ferruginea* poorly represented (<5%), Taxus brevifolia well represented (≥5%) .... -TAXUS BREVIFOLIA phase
   c. *T. brevifolia* poorly represented (<5%), Xerophyllum tenax well represented (≥5%) .... -XEROPHYLLUM TENAX phase
   d. Not as above .... -CLINTONIA UNIFLORA phase
6. *C. uniflora, T. trifoliata,* and *C. occidentalis* absent, then,
   a. Reevaluate choice of *Thuja plicata* as appropriate series, and
   b. Note that closed canopy successional stages may have exceedingly depauperate undergrowths; in these cases, examine the closest stand with similar site variables but having a canopy structure permitting undergrowth development and reenter key;
   c. A small percentage of THPL sites, usually on edaphically atypical sites, appear incapable of supporting the mesic undergrowth species enumerated above; exhausting the above choices designate stand as .... THPL SERIES (p. 26)

C. *Tsuga mertensiana* Series; Key to Habitat Types

1. Sites supporting a variable combination of the following species, their single or combined coverages common (≥1%), *Streptopus amplexifolius, Senecio triangularis, Trautvetteria caroliniensis, Ligusticum canbyi, Mitella breweri,* or *M. pentandra* .... TSME/STREPTOPUS AMPLEXIFOLIUS h.t. (p. 37)
   a. *Luzula hitchcockii* or *Phyllodoce empetriformis* or their combined coverages common (≥1%) .... -LUZULA HITCHCOCKII phase
   b. Not as above .... -MENZIESIA FERRUGINEA phase
1. Not as above 2

2. *Clintonia uniflora* or *Tiarella trifoliata* present and not restricted to microsites, or *Coptis occidentalis* common (≥1%) .... TSME/CLINTONIA UNIFLORA h.t. (p. 38)
   a. *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
   b. *M. ferruginea* poorly represented, *Xerophyllum tenax* common (≥1%) .... -XEROPHYLLUM TENAX phase
   c. *X. tenax* scarce (<1%) .... /C. UNIFLORA h.t. (p. 38)
2. *C. uniflora* and *T. trifoliata* absent, *C. occidentalis* scarce (<1%) 3

3. *Menziesia ferruginea* well represented (≥5%) .... TSME/MENZIESIA FERRUGINEA h.t. (p. 40)
   a. *Luzula hitchcockii* or *Phyllodoce empetriformis* or their combined coverages common (≥1%) .... -LUZULA HITCHCOCKII phase
   b. Not as above, *Xerophyllum tenax* common (≥1%) .... -XEROPHYLLUM TENAX phase
   c. *X. tenax* scarce (<1%) .... /M. FERRUGINEA h.t. (p. 40)
3. *M. ferruginea* poorly represented (<5%) 4

4. *Xerophyllum tenax* common (≥1%) .... TSME/XEROPHYLLUM TENAX h.t. (p. 43)
   a. *Luzula hitchcockii* or *Phyllodoce empetriformis* or their combined coverages common (≥1%) .... -LUZULA HITCHCOCKII phase
   b. Not as above, *Vaccinium scoparium* (*V. myrtillus*) well represented (≥5%) .... -VACCINIUM SCOPARIUM phase
   c. Not as above, *V. scoparium* (*V. myrtillus*) poorly represented (<5%) .... -XEROPHYLLUM TENAX phase
4. *X. tenax* scarce (<1%) 5

5. *Luzula hitchcockii* common (≥1%) .... TSME/LUZULA HITCHCOCKII h.t. (p. 44)
5. *L hitchcockii* scarce (<1%) .... TSME SERIES (p. 36)

D. *Abies lasiocarpa* Series; Key to Habitat Types

1. *Calamagrostis canadensis* or *Ledum glandulosum* well represented (>5%) .... ABLA/CALAMAGROSTIS CANADENSIS h.t (p.46)
   a. *Ledum glandulosum* well represented (≥5%) .... -LEDUM GLANDULOSUM phase
   b. Not as above, *Vaccinium caespitosum* common (≥1%) .... -VACCINIUM CAESPITOSUM phase
   c. Not as above, *Ligusticum canbyi* or *Trautvetteria caroliniensis* common (≥1%) .... -LIGUSTICUM CANBYI phase
   d. Not as above *C. canadensis* undergrowth dominant .... -CALAMAGROSTIS CANADENSIS phase
1. *C. canadensis* and *L. glandulosum* poorly represented (<5%) 2

2. *Streptopus amplexifolius, Senecio triangularis, Ligusticum canbyi, Mitella breweri, M. pentandra, Gymnocarpium dryopteris,* or *Trautvetteria caroliniensis* singly, or in combination of two or more, common (≥1%) .... ABLA/STREPTOPUS AMPLEXIFOLIUS h.t. (p.48)
   a. *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
   b. *M. ferruginea* poorly represented (<5%) .... -LIGUSTICUM CANBYI phase
2. Not as above 3

3. *Clintonia uniflora* present, not restricted to microsites .... ABLA/CLINTONIA UNIFLORA h.t. (p.50)
   a. *Menziesia ferruginea* or *Rhododendron albiflorum* well represented (≥5%) .... MENZIESIA FERRUGINEA phase
   b. *M. ferruginea* and *R. albiflorum* poorly represented (<5%), *Xerophyllum tenax* common (≥1%) . ... -XEROPHYLLUM TENAX phase
   c. *X. tenax* scarce (<1%) .... CLINTONIA UNIFLORA phase
3. *C. uniflora* absent or restricted to microsites 4

4. *Menziesia ferruginea* or *Rhododendron albiflorum* well represented (>5%) .... ABLA/MENZIESIA FERRUGINEA h.t. (p.52)
   a. *Luzula hitchcockii* common (≥1%) .... -LUZULA HITCHCOCKII phase
   b. *L. hitchcockii* scarce (<1%), *Vaccinium scoparium* (*V. myrtillus*) common (≥1%) .... -VACCINIUM SCOPARIUM phase
   c. Not as above, *Coptis occidentalis* present, not restricted to microsites .... -COPTIS OCCIDENTALIS phase
   d. *C. occidentalis* absent, *Xerophyllum tenax* common (≥1%) .... -XEROPHYLLUM TENAX phase
   e. *X. tenax* scarce (<1%) .... /M. FERRUGINEA h.t. (p. 55)
4. *M. ferruginea* and *R. albiflorum* poorly represented (<5%) 5

Figure 3—(con.)

5. *Vaccinium caespitosum* common (≥1%) .... ABLA/VACCINIUM CAESPITOSUM h.t. (p.54)
5. *V. caespitosum* scarce (<1%) 6

6. *Xerophyllum tenax* common (≥1%) .... ABLA/XEROPHYLLUM TENAX h.t. (p. 55)
 a. *Luzula hitchcockii* common (≥1%) .... -LUZULA HITCHCOCKII phase
 b. *L. hitchcockii* scarce (<1%), *Vaccinium scoparium* (*V. myrtillus*) well represented (≥5%) .... -VACCINIUM SCOPARIUM phase
 c. Not as above, *Coptis occidentalis* present, not restricted to microsites .... -COPTIS OCCIDENTALIS phase
 d. Not as above, *Vaccinium globulare* common (≥1%) .... -VACCINIUM GLOBULARE phase
 e. Not as above .... /X. TENAX h.t. (p. 55)
6. *X. tenax* scarce (<1%) 7

7. *Luzula hitchcockii* common (≥1%) .... ABLA/LUZULA HITCHCOCKII h.t. (p. 57)
7. *L. hitchcockii* scarce (<1%) 8

8. *Vaccinium globulare* well represented (≥5%) .... ABLA/VACCINIUM GLOBULARE h.t. (see Pfister a others (1977))
8. *V. globulare* poorly represented (<5%) 9

9. *Vaccinium scoparium* (or *V. myrtillus*) well represented (≥5%) .... ABLA/VACCINIUM SCOPARIUM h.t. (p. 57) 9
9. *V. scoparium* (*V. myrtillus*) poorly represented (<5%) 10

10. *Calamagrostis rubescens* well represented (≥5%) .... ABLA/CALAMAGROSTIS RUBESCENS h.t. (see Pfister and others (1977))
10. *C. rubescens* poorly represented (<5%) 11

11. *Larix lyallii* present .... LARIX LYALLII-ABIES LASIOCARPA h.t.'s (p. 58)
11. *L. lyallii* absent, *Pinus albicaulis* well represented (≥5%) .... PINUS ALBICAULIS-ABIES LASIOCARPA h.t.'s (p.58)

E. *Abies grandis* Series; Key to Habitat Types

1. Sites supporting any of the following wet-site species well represented (≥5%) or a variable combination of at least two species, whose single or combined coverages are common (≥1%), *Senecio triangularis, Streptopus amplexifolius, Ligusticum canbyi, Trautvetteria caroliniensis,* or *Athyrium filix-femina* .... ABGR/SENECIO TRIANGULARIS h.t. (p. 60)
1. Not as above, not characterized by combination of wet-site species cited above 2

2. *Asarum caudatum* present, not restricted to microsites .... ABGR/ASARUM CAUDATUM h.t. (p. 61)
 a. *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
 b. *M. ferruginea* poorly represented (<5%), *Taxus brevifolia* well represented (≥5%) .... -TAXUS BREVIFOLIA phase
 c. Not as above, *T. brevifolia* poorly represented (<5%) .... -ASARUM CAUDATUM phase
2. *A. caudatum* absent or restricted to microsites 3

3. *Clintonia uniflora* or *Tiarella trifoliata* present, not restricted to microsites .... ABGR/CLINTONIA UNIFLORA h.t. (p. 63)
 a. *Menziesia ferruginea* well represented (≥5%) .... -MENZIESIA FERRUGINEA phase
 b. *M. ferruginea* poorly represented (<5%), *Taxus brevifolia* well represented (≥5%) .... -TAXUS BREVIFOLIA phase
 c. Not as above, *Xerophyllum tenax* common (≥1%) .... -XEROPHYLLUM TENAX phase
 d. *X. tenax* scarce (<1%); *Physocarpus malvaceus* or *Holodiscus discolor* well represented (≥5%) .... -PHYSOCARPUS MALVACEUS phase
 e. Not as above, *P. malvaceus* and *H. discolor* poorly represented (<5%) .... -CLINTONIA UNIFLORA phase
3. *C. uniflora* and *T. trifoliata* absent, or restricted to microsites 4

4. *Linnaea borealis* common (≥1%) .... ABGR/LINNAEA BOREALIS h.t. (p. 68)
 a. *Xerophyllum tenax* common (≥1%) .... -XEROPHYLLUM TENAX phase
 b. *X. tenax* scarce (<1%) .... -LINNAEA BOREALIS phase
4. *L. borealis* scarce (<1%) 5

5. *Xerophyllum tenax* well represented or *Coptis occidentalis* common (≥1%) (≥5%) .... ABGR/XEROPHYLLUM TENAX h.t. (p. 69)
 a. *Coptis occidentalis* common (≥1%) .... -COPTIS OCCIDENTALIS phase
 b. *C. occidentalis* scarce (<1%), *Vaccinium globulare* common (≥1%) .... VACCINIUM GLOBULARE phase
 c. *Vaccinium globulare* scarce (<1%) .... /X. TENAX h.t. (p. 69)
5. *X. tenax* poorly represented (<5%) and *C. occidentalis* scarce (<1%) 6

6. *Vaccinium globulare* (*V. membranaceum*) well represented (≥5%) .... ABGR/VACCINIUM GLOBULARE h.t. (p. 71)
6. *V. globulare* poorly represented (<5%) 7

7. *Physocarpus malvaceus* or *Holodiscus discolor* or their combined coverages well represented (≥5%) .... ABGR/PHYSOCARPUS MALVACEUS h.t. (p. 71)
 a. *Coptis occidentalis* common (≥1%) .... -COPTIS OCCIDENTALIS phase
 b. *C. occidentalis* scarce (<1%) .... -PHYSOCARPUS MALVACEUS phase
7. *P. malvaceus* and *H. discolor* or their combined coverage poorly represented (<5%) 8

8. *Spiraea betulifolia* or *Symphoricarpos albus* well represented (≥5%) .... ABGR/SPIRAEA BETULIFOLIA h.t. (p. 72)
8. *S. betulifolia* and *S. albus* poorly represented (<5%) .... ABGR SERIES (p. 59)

F. *Pseudotsuga menziesii* Series; Key to Habitat Types

1. *Physocarpus malvaceus, Holodiscus discolor* or their combined coverages well represented (≥5%) .... PSME/PHYSOCARPUS MALVACEUS h.t. (p. 73)
 a. *Disporum hookeri* or *Smilacina stellata* present; or *Larix occidentalis* or *Galium triflorum* common (≥1%) .... -SMILACINA STELLATA phase
 b. Not as above .... -PHYSOCARPUS MALVACEUS phase
1. *P. malvaceus* and *H. discolor*, singly or combined coverages, poorly represented (<5%) 2

Figure 3—(con.)

2. *Vaccinium caespitosum* present, not restricted to microsites; *Arctostaphylos uva-ursi* common (≥1%) .... PSME/VACCINIUM CAESPITOSUM h.t. (p. 75)
2. *V. caespitosum* absent and/or *A. uva-ursi* scarce (<1%).......... 3

3. *Xerophyllum tenax* or *Vaccinium globulare* well represented (≥5%).......... PSME/VACCINIUM GLOBULARE h.t. (p. 75)
3. *X. tenax* or *V. globulare* poorly represented (<5%).......... 4

4. *Symphoricarpos albus* well represented (≥5%).......... PSME/SYMPHORICARPOS ALBUS h.t. (p. 75)
4. *S. albus* poorly represented (<5%) 5

5. *Spiraea betulifolia* well represented (≥5%) .... PSME/SPIRAEA BETULIFOLIA h.t. (p. 76)
5. *S. betulifolia* poorly represented (<5%) 6

6. *Calamagrostis rubescens* singly or in combination with *Arctostaphylos uva-ursi* well represented (≥5%) .... PSME/CALAMAGROSTIS RUBESCENS h.t. (p. 76)
   a. *A. uva-ursi* present, not restricted to microsites.......... -ARCTOSTAPHYLOS UVA-URSI phase
   b. *A. uva-ursi* absent .... -CALAMAGROSTIS RUBESCENS phase
6. *C. rubescens* and *A. uva-ursi*, singly or combined, poorly represented (<5%).......... 7

7. *Carex geyeri* well represented (≥5%) .... PSME/CAREX GEYERI h.t. (p. 76)
7. *C. geyeri* poorly represented (<5%).......... 8

8. *Festuca idahoensis* well represented (≥5%).......... PSME/FESTUCA IDAHOENSIS h.t. (p. 76)
8. *F. idahoensis* poorly represented (<5%) 9

9. *Agropyron spicatum* well represented (≥5%) .... PSME/AGROPYRON SPICATUM h.t. (p. 77)
9. *A. spicatum* poorly represented (<5%) .... PSME SERIES (p. 72)

G. *Pinus contorta* Series; Key to Habitat and Community Types

For identification of plant communities in which tree species other than *Pinus contorta* are a minor component; *P. contorta* need not appear to be self-reproducing. See indicated h.t. key for phase level identification and ADP number.

1. *Calamagrostis canadensis* or *Ledum glandulosum* well represented (≥5%).......... ABLA/CALAMAGROSTIS CANADENSIS h.t. (p. 46)
1. *C. canadensis* or *L. glandulosum* poorly represented (<5%).......... 2

2. *Streptopus amplexifolius, Senecio triangularis, Ligusticum canbyi, Mitella pentandra, Gymnocarpium dryopteris,* or *Trautvetteria caroliniensis,* singly or in combinations, common (≥1%) .... ABLA/STREPTOPUS AMPLEXIFOLIUS h.t. (p. 37)
2. The above cited species, singly or in combinations, scarce (<1%).......... 3

3. *Asarum caudatum, Clintonia uniflora, Tiarella trifoliata, or Coptis occidentalis present,* or *Linnaea borealis* common (≥1%) .... See a.- e.
   a. Within *Tsuga heterophylla* zone[1] .... TSHE/ASARUM CAUDATUM or CLINTONIA UNIFLORA h.t.'s (pages 21,23,32,34)
   b. Within *Thuja plicata* zone .... THPL/as above
   c. Within *Abies grandis* zone .... ABGR/as above, or LINNAEA BOREALIS h.t. (pages 61,63,68)
   d. Within *Tsuga mertensiana* zone .... TSME/CLINTONIA UNIFLORA h.t. (p. 38)
   e. Within *Abies lasiocarpa* zone . ... .ABLA/CLINTONIA UNIFLORA h.t. (p. 50)
3. *A. caudatum, C. uniflora, T. trifoliata,* or *C. occidentalis* absent; or *L. borealis* scarce (<1%).......... 4

4. *Xerophyllum tenax* common (≥1%), or *Menziesia ferruginea* well represented (≥5%).......... See a.- e.
   a. Within the *T. heterophylla* zone .... TSHE/MENZIESIA FERRUGINEA h.t. (p. 26)
   b. Within the *T. mertensiana* zone .... TSME/XEROPHYLLUM TENAX or MENZIESIA FERRUGINEA h.t.'s (p. 43 & 40)
   c. Within the *A. grandis* zone .... ABGR/XEROPHYLLUM TENAX h.t. (p. 69)
   d. Within the *A. lasiocarpa* zone .... See (1)
      (1) *M. ferruginea* well represented (≥5%) .... ABLA/MENZIESIA FERRUGINEA h.t. (p. 52)
      (1) *M. ferruginea* poorly represented (<5%).......... See (2)
      (2) *A. lasiocarpa* or *Picea engelmannii* regeneration, if present, not severely stunted, *Vaccinium globulare* well represented (≥5%), soils[2] deeper than 12 inches (30 cm) .... ABLA/XEROPHYLLUM TENAX h.t. (p. 55)
      (2) *A. lasiocarpa* and *P. engelmannii* regeneration, if present, severely stunted, *V. globulare* poorly represented (<5%), *V. scoparium* well represented (≥5%), and soils[2] shallower than 12 inches (30 cm) and very well drained.......... PICO/VACCINIUM SCOPARIUM h.t. (p. 79)
   e. *Pinus contorta* the only reproducing species for extensive areas .... See (1)
      (1) *Vaccinium caespitosum* common (≥1%).......... PICO/VACCINIUM CAESPITOSUM c.t (p. 79)
      (1) *V. caespitosum* scarce (<1%) 2
      (2) *Vaccinium globulare* well represented (≥5%), soils[2] deeper than 12 inches (30 cm) .... PICO/XEROPHYLLUM TENAX c.t. (p. 79)
      (2) *V. globulare* poorly represented (<5%), soils[2] shallower than 12 inches (30 cm) .... PICO/VACCINIUM SCOPARIUM h.t. (p. 79)
4. *X. tenax* scarce (<1%) or *M. ferruginea* poorly represented (<5%).......... 5

5. Within the *Abies grandis* zone .... ABGR SERIES, couplet 4
5. Not within the *A. grandis* zone, but rather *A. lasiocarpa* zone 6

Figure 3—(con.)

6. *Abies lasiocarpa* or *Picea engelmannii* regeneration, if present, not severely stunted, *Vaccinium globulare* or *Calamagrostis rubescens* well represented (<5%), and soils[2] deeper than 12 inches (30 cm) .... ABLA SERIES, couplet 8
6. *A. lasiocarpa* and *P. engelmannii* regeneration, if present, severely stunted, *V. globulare* and *C. rubescens* poorly represented (<5%); soils[2] shallower than 12 inches (30 cm) and well drained .... See lead 4.e. above

[1]Zone = area potentially occupied by a given climax tree species on locally normal soils and topography, and no evidence that tree's presence is dependent on recurrent disturbance.

[2]Soil depths = the depth from top of mineral soil surface (A and B horizons) to the top of weathered parent material (C horizon) or bedrock (R horizon), whichever is least. Depth should be sampled on an average topographic position for the site, and more than once if questions remain.

H. Pinus ponderosa Series; Key to Habitat Types

1. *Physocarpus malvaceus* or *Holodiscus discolor* or their combined coverages well represented (≥5%) .... PIPO/PHYSOCARPUS MALVACEUS h.t. (p. 87)
1. *P. malvaceus* and *H. discolor* poorly represented (<5%) 2

2. *Symphoricarpos albus* or *Berberis repens* or their combined coverages well represented (≥5%) .... PIPO/SYMPHORICARPOS ALBUS h.t. (p. 81)
2. *S. albus* and *B. repens* poorly represented (<5%) 3

3. *Festuca idahoensis* well represented (≥5%) .... PIPO/FESTUCA IDAHOENSIS h.t. (p. 82)
3. *F. idahoensis* poorly represented (<5%) 4

4. *Agropyron spicatum* well represented (≥5%) .... PIPO/AGROPYRON SPICATUM h.t. (p. 83)
4. *A. spicatum* poorly represented (<5%) .... PIPO SERIES (p. 80)

Figure 3—(con.)

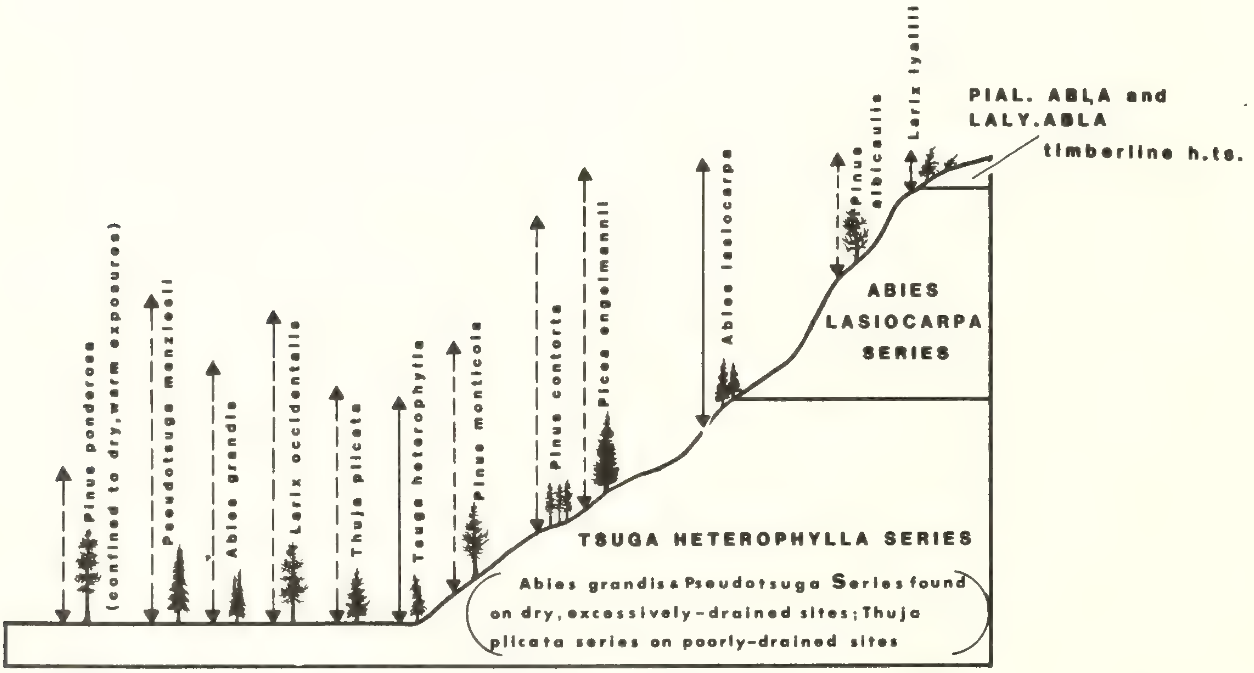


Figure 4—Generalized distribution of forest tree species in northernmost Idaho.

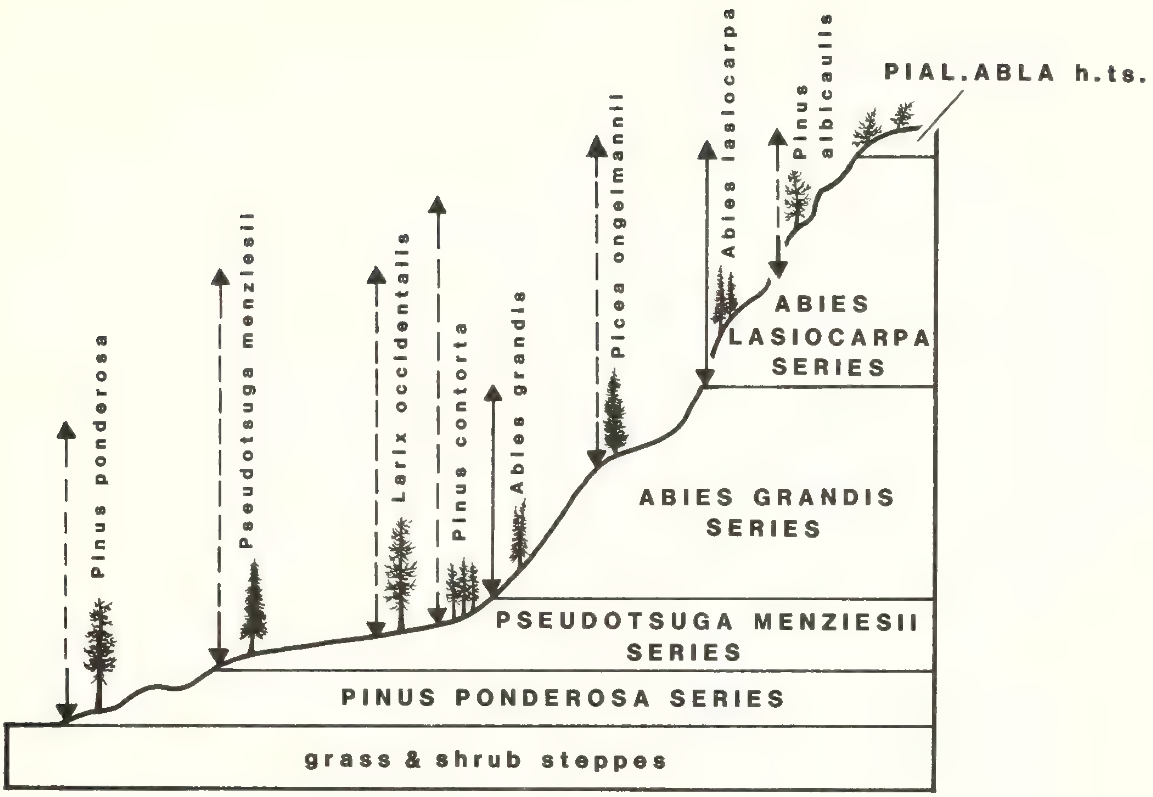


Figure 5—Generalized distribution of forest tree species on the west-central portion of the Nez Perce NF.

Tsuga heterophylla (TSHE) Series

Distribution—Of the climax tree species occurring in northern Idaho, *Tsuga heterophylla* is the most shade tolerant, least frost hardy, and has been ranked second to *T. mertensiana* for intolerance to drought and second to *Pseudotsuga menziesii* for intolerance to excess moisture (Minore 1979). Due to its restricted ecologic amplitude, plant communities dominated by *Tsuga* occupy the moist, moderate temperature sites within the maritime-influenced climatic zone of the Northern Rocky Mountains. Nevertheless, communities occur extensively, the Idaho Panhandle National Forests (St. Joe, Coeur d'Alene, and Kaniksu) being their center of importance. Their southern extension abruptly ends at the North Fork Clearwater River drainage. The easternmost limit of this series is the McDonald Lake drainage in Glacier National Park (Habeck 1968), while westward it extends (considering only interior populations) to the Columbia River drainage in northeastern Washington (Daubenmire and Daubenmire 1968; Williams and Lillybridge 1984).

Tsuga heterophylla can be found as the climax-dominant tree from 2,500 to 5,500 ft (760 to 1,680 m) in elevation, its occurrence increasing in elevation along a north-to-south transect. It occurs in areas having greater than 30 inches (76 cm) mean annual precipitation and greater than 8 inches (20 cm) average warm-season precipitation (Ross and Savage 1967). It can dominate sites of all exposures, landform, and position except wet bottomlands where it is replaced by or codominant with *Thuja plicata*. At the lower elevational boundary of this series, *Tsuga* is replaced by *Thuja* on both wetter and drier sites. *Thuja*, compared to *Tsuga*, appears to be more tolerant of short drought periods in the summer and excessive soil moisture, while also being better adapted to warmer temperatures (Minore 1979). At the upper elevational limits, *T. heterophylla* is replaced by either *T. mertensiana* or *Abies lasiocarpa*; this shift in species dominance appears to be a function of low summer temperature (Daubenmire and Daubenmire 1968), but is probably also related to mean annual and mean summer precipitation.

Vegetation—All endemic tree species except *Pinus ponderosa, Larix lyallii, Pinus albicaulis*, and *Tsuga mertensiana* act as major seral species within this series. Some of these species are very long-lived and codominate sites for extended periods of time. Daubenmire and Daubenmire (1968) mention relict *Pinus monticola* 450 years of age in *Tsuga* stands. Areas on the Priest Lake Ranger District currently support *Thuja* as a codominant, with estimated stand ages in excess of 800 years. This long-term, late seral condition has led to formal classifications of *Thuja-Tsuga* types and widespread common usage of the name "cedar-hemlock forest." Because of the exceptionally long duration of these successional stages and the

lack of data showing a true *Tsuga* dominance on excessively wet areas (sites with well-represented coverages of *Oplopanax horridum*, *Athyrium filix-femina*, and/or *Adiantum pedatum*), these sites have been placed in the *Thuja* series. Only sites potentially dominated by *Tsuga*, the better drained upland environments, are described in this section.

The undergrowth in this series is characterized by species with an affinity for the Pacific Maritime climatic regime. All *Tsuga* sites support members of what Daubenmire (1952) termed the *Pachistima myrsinites* union. Daubenmire and Daubenmire (1968) stated "analysis of the data representing 19 old virgin stands. . . reveals no significant floristic gradients." Our much larger data set, 120 stands, including 11 of the Daubenmires' original stands, shows species compositional groups indicative of significant differences relating to site productivities and response to management. The understory vegetation has four major communities corresponding to a moisture gradient, the wettest group being those already discussed as members of the *Tsuga-Thuja* complex (OPHO, ATFI, and ADPE). The driest group we have classified as the *Clintonia uniflora* h.t., roughly equivalent to the Daubenmires' *Pachistima* h.t. Two intermediate groups characterized by the presence of *Asarum caudatum* and *Gymnocarpium dryopteris* occupy a transition regime of increasing moisture.

Old-growth stands of this series have an open and occasionally almost parklike nature, with 75 to 95 percent canopy closure, large-diameter (30- to 50-inch [76- to 127-cm] d.b.h.) trees, and two-storied to multistoried stand structure. Early to midseral stands are quite the opposite. Canopy closure is complete to the extent that very little light reaches the forest floor. Occupancy of the site by trees can exclude all but the most shade tolerant of understory species, creating very sparse shrub and herbaceous layers. Classification of sites such as these will require inspection of adjacent more open stands having similar environmental characteristics (slope, aspect, soils, landform, etc.).

Productivity/Management—The *Tsuga heterophylla* and *Thuja plicata* series occupy the most productive habitats in northern Idaho. Comparing the two, we find the following tree species to have slightly higher site indexes when growing in the *Tsuga* zone: *Abies grandis*, *A. lasiocarpa*, *Larix occidentalis*, *P. contorta*, *P. monticola*, *T. heterophylla*. Within this series natural regeneration 20 years following various silvicultural treatments is usually significant in quantity (Boyd 1969). Any disturbance in existing stands can result in tremendous *Tsuga* regeneration (Graham 1982). *Abies grandis*, *P. monticola*, and *T. heterophylla* are the major components of these naturally regenerated sites. Some attempts at *Pinus ponderosa* plantations in this series have been failures (Daubenmire 1961). Use of *P. ponderosa* in a planting mixture should be successful on the warmest, driest sites of this series; there are tentative indications though that the seed source should come from the *Tsuga* series (Rehfeldt 1983).

Natural regeneration should be successful if adequate seed is available. Ferguson and others (1986) have developed a regeneration model as a submodel to Stage's (1973) Prognosis Model; their model uses the silvical characteristics of Northern Rocky Mountain conifer species and site data stratified by habitat type and treatment to predict regeneration success.

Tsuga heterophylla/Gymnocarpium dryopteris h.t. (TSHE/GYDR; western hemlock/oak fern)

Distribution—TSHE/GYDR is widespread in the forested region north of Coeur d'Alene, but is also found sporadically as far south as Moscow. It occurs at elevations ranging from 2,500 to 4,500 ft (760 to 1,370 m) on moderate slopes or benches on the lower third of slopes. This h.t. is generally not found on southerly aspects.

Vegetation—*Tsuga* dominates the site in late seral to climax stages. This is the wettest h.t. in the *Tsuga* series. *Thuja* was found as a mid to late-seral species in half of our stands; it persists with much reduced numbers in climax stands. *Abies grandis*, *Pinus monticola*, and *Picea engelmannii* are the other major seral species, with *Larix occidentalis* and *Abies lasiocarpa* represented by scattered individuals in many mature stands.

The undergrowth is characterized by a rich mixture of shrubs and forbs requiring moderate temperatures and abundant moisture. In addition to *Gymnocarpium dryopteris* being well represented, all sites support *Clintonia uniflora*, *Coptis occidentalis*, *Asarum caudatum*, *Disporum hookeri*, *Smilacina stellata*, *Tiarella trifoliata*, *Trillium ovatum*, and *Viola orbiculata*, with most sites also supporting a low coverage of *Athyrium filix-femina* (fig. 6). *Lonicera utahensis*, *Pachistima myrsinites*, and *Linnaea borealis* are common shrub species in this h.t., with *Menziesia ferruginea*, *Vaccinium globulare*, and *Taxus brevifolia* often present in low amounts.

Soils—Parent materials are mostly ash over quartzite, but also include siltite, metasediments, and glacial till. Textures are predominantly loams or sandy loams, with 30 to 50 percent gravel. Total soil depth ranges between 15 and 28 inches (40 and 70 cm), and pH ranges between 4.9 and 6.0. Bare soil and rock usually do not occur on these sites. Average litter depth is 2 inches (5 cm).

Productivity/Management—High site indexes and basal areas indicate high timber productivity. *Abies grandis*, *L. occidentalis*, *T. plicata*, and *P. engelmannii* achieve some of their highest site indexes in this h.t. (appendix F). *Pinus monticola* does well here, but better growth is achieved on slightly drier sites. Short-rotation, even-aged management of *L. occidentalis*, *P. engelmannii*, and/or *P. monticola* is currently the preferred management regime. The soils remain moist throughout the year; logging operations should be scheduled such that desirable soil characteristics are not unduly modified. Mature stands within this type have a high percentage of the trees with extensive heartrot (for example, *Echinodontium tinctorum*, *Fomes pini*, and *Polyporus tomentosus*). Windthrow and root rot pockets give the mature stand a rather open character. Forage production for big game is good during early seral stages, poor during the closed canopy mid- to late-seral stages, and fair in mature stands.

Other Studies—This h.t. has not been previously described. TSHE/GYDR is equivalent to the wettest sites

Figure 6—*Tsuga heterophylla/Gymnocarpium dryopteris* h.t. on a toeslope, covelike position (3,200 ft [975 m]) just east of the Magee Work Center, Coeur d'Alene NF. A 90-year-old stand dominated by *T. heterophylla* with a mix of seral tree species. Abundant coverage of *G. dryopteris* is obscured by the rank growth of larger herbs including *Trautvetteria caroliniensis*, *Tiarella trifoliata*, *Smilacina stellata*, *Coptis occidentalis*, and scattered *Athyrium filix-femina*.

described as the *Tsuga/Pachistima myrsinites* h.t. by Daubenmire and Daubenmire (1968); five of their sample plots in northern Idaho are used in this data set. Pfister and others (1977) describe an environment similar to this h.t. as a portion of THPL/CLUN-ARNU in northwestern Montana.

Tsuga heterophylla/Asarum caudatum h.t. (TSHE/ASCA; western hemlock/wild ginger)

Distribution—TSHE/ASCA is a broadly distributed h.t. that increases in occurrence from the St. Joe NF northward to the Canadian border. If temperature and soil moisture are adequate, TSHE/ASCA can occupy any landform or slope position at elevations ranging from 2,200 to 5,000 ft (670 to 1,520 m). Two of the phases delineated are related to distinctive topographic, aspect, and elevational factors. At the dry extreme of this h.t., it merges with TSHE/CLUN and occasionally THPL/CLUN, while on more moist sites it grades to TSHE/GYDR or one of the *Tsuga-Thuja* codominant fern h.t.'s. In an ordination of h.t.'s of northern Idaho based on a multidimensional environmental gradient of precipitation, temperature, soil moisture, and numerous other site factors, TSHE/ASCA is the most centrally located h.t. along any of the gradients.

Vegetation—All conifer species of northern Idaho, except *Larix lyallii*, *Pinus albicaulis*, and *Tsuga mertensiana*, can occur in this h.t. The dominant successional species are *Abies grandis*, *Larix occidentalis*, *Thuja plicata*, *Pinus monticola*, and *Pseudotsuga menziesii*. *Thuja plicata* is often a minor component in climax (old-growth) stands. *Pinus contorta* locally constitutes an important seral species forming nearly pure stands. Early to midsuccessional stands often have seven or eight conifer species represented. The shrub and herbaceous layers are just as diverse, with an average of eight shrub species and 15 to 20 herbaceous species present on all but the most closed-canopy late successional stands. The presence of *Asarum caudatum* throughout the stand is diagnostic of the h.t. High constancy of *Clintonia uniflora*, *Coptis occidentalis*, *Disporum hookeri*, *Adenocaulon bicolor*, and *Tiarella trifoliata* is also characteristic of this type. The shrub species *Linnaea borealis*, *Lonicera utahensis*, *Pachistima myrsinites*, *Rosa gymnocarpa*, and *Vaccinium globulare* also exhibit high constancy in TSHE/ASCA.

Aralia nudicaulis (ARNU) phase—The ARNU phase is found on sites north of the Coeur d'Alene River. It generally occurs below 3,000 ft (910 m), on bottomlands, toeslopes, or the first bench above a wet bottom. This is the warmest, most moist phase of the TSHE/ASCA h.t.

The ARNU phase is characterized by the presence of *Aralia nudicaulis* throughout the stand (fig 7). *Athyrium filix-femina* and *Gymnocarpium dryopteris* are usually present, but generally not exceeding trace amounts. In addition to the understory species listed above as common to this h.t., this phase shows increased constancy for *Acer glabrum*, *Chimaphila umbellata*, and *Goodyera oblongifolia*, and a reduced occurrence of *Coptis occidentalis*. *Thuja plicata* is the major seral species, often remaining as a climax codominant due to the mosaic of wet microsites that abound in these stands. Adjacent upslope h.t.'s are generally TSHE/ASCA-ASCA, and downslope on wetter sites, TSHE/GYDR or THPL/ATFI.

Menziesia ferruginea (MEFE) phase—The MEFE phase occurs throughout the range of TSHE/ASCA at elevations above 3,500 ft (1,070 m) and generally on northwest to northeast aspects. This phase occupies the cold, moist portion of TSHE/ASCA. With a shift to drier, more southerly aspects, *M. ferruginea* decreases in coverage and *Xerophyllum tenax* increases. Major seral trees in the MEFE phase are *Abies lasiocarpa* and *Picea engelmannii*. In addition to the characteristically dominant *M. ferruginea* and *Vaccinium globulare* shrub layer, *Arnica latifolia* and *X. tenax* are common herbaceous species.

Asarum caudatum (ASCA) phase—The ASCA phase is commonly distributed from the St. Joe NF to the south end of Priest Lake (occurring only sporadically northward), at elevations between 2,200 and 4,500 ft (670 and 1,370 m). It occurs on all aspects, landforms, and slopes but is more prevalent on warm exposures. Major seral trees are *Abies grandis*, *Larix occidentalis*, *Pinus monticola*, and *Pseudotsuga menziesii*, with *Thuja plicata* often being a late seral codominant. The shrub and herbaceous layers are rich in species as described above for the h.t. The ASCA phase of TSHE/ASCA usually is located adjacent to TSHE/CLUN-CLUN or THPL/ASCA h.t. on drier sites, and grades into TSHE/GYDR or TSHE/ASCA-ARNU on more moist sites.

Soils—Parent materials are quartzite, sandstone, siltite, and metasediments, with an ash cap or mantle of mixed loess and volcanic material. The predominant textural classes are loam to silty-loam and occasionally clay-loam. Gravel content ranges from 30 to 60 percent in the ARNU and MEFE phases, only 10 percent being normal for the ASCA phase. Total soil depth ranges between 12 and 26 inches (30 and 65 cm), and average pH varies widely, from 4.5 to 6.7. Bare soil and rock usually do not occur; litter depth averages 1.5 inches (4 cm).

Figure 7—*Tsuga heterophylla/Asarum caudatum* h.t.-*Aralia nudicaulis* phase on a stream terrace (2,500 ft [760 m]) above Lightning Creek, north of Clark Fork, ID. Dominated by even-aged *Betula papyrifera*, *Larix occidentalis*, and *Pseudotsuga menziesii*, the stand is decidedly uneven-aged due to the continuous ingrowth of *Thuja plicata*, *Abies grandis*, and comparatively recently, *T. heterophylla*. Seventeen shrub species are present, none in more than trace amounts. The rich herbaceous layer is dominated by *Smilacina stellata*, *A. caudatum*, *Adenocaulon bicolor*, and *A. nudicaulis* (noted in left foreground by its distinctive horizontally oriented leaflets).

Productivity/Management—Of the extensively occurring h.t.'s in northern Idaho, TSHE/ASCA is the most productive (appendix F). Excellent height growth is achieved by *P. menziesii*, *L. occidentalis*, *P. monticola*, and *A. grandis* on this h.t. Any natural or artificial regeneration treatment should be successful; the main problem is the potential for overstocked stands. Shelterwood or selection treatments will favor regeneration of *A. grandis*, *T. plicata*, *T. heterophylla*, *P. engelmannii*, and/or *A. lasiocarpa*.

Inherent high productivity of these sites can lead to heavy shrub competition, particularly if shrub establishment is allowed to precede tree regeneration by a year or two. Seasonally wet soils in the ARNU phase are subject to compaction during most of the year. Large herbivores and rodents may do extensive damage during early stages of regeneration. Stands with high coverages of shrubs, particularly *Taxus brevifolia* and *Vaccinium globulare*, may provide significant moose, elk, and grizzly bear habitat.

Other Studies—This h.t. has not been previously described. TSHE/ASCA was included as a portion of the *Tsuga/Pachistima myrsinites* h.t. of Daubenmire and Daubenmire (1968). In northern Idaho this type appears to be restricted to the central portion of the Inland Pacific Maritime climatic influence; however, analogous communities undoubtedly occur west of the Cascades in Oregon and Washington.

Tsuga heterophylla/Clintonia uniflora h.t. (TSHE/CLUN; western hemlock/queencup beadlily)

Distribution—Of the *Tsuga* h.t.'s in northern Idaho, TSHE/CLUN is the most widely distributed. It can be found from the Canadian border to the North Fork Clearwater River drainage. Its elevational range is from 2,500 to 5,200 ft (760 to 1,580 m), with all aspects, slopes, and landforms being represented. TSHE/CLUN is the driest environment capable of supporting *Tsuga*. Slightly drier sites constitute THPL/CLUN, ABGR/CLUN, or ABLA/CLUN h.t.'s, while on more moist sites TSHE/CLUN may merge with TSHE/ASCA or THPL/ASCA h.t.'s.

Vegetation—Seral species that may dominate early successional stages are *Pseudotsuga menziesii*, *Larix occidentalis*, *Pinus monticola*, and *Pinus contorta*. Species found as codominants in mid- to late-seral stands and occasional individuals in old-growth stands are *Abies grandis*, *Abies lasiocarpa*, *Picea engelmannii*, and *Thuja plicata*. In successional stands of the *Tsuga* series, great care must be taken when determining the most tolerant, successfully reproducing tree species, because nearly all northern Idaho species, including *Pinus ponderosa*, may be present.

TSHE/CLUN shrub and herbaceous layers are species rich. Most sites have a low coverage of *Lonicera utahensis*, *Pachistima myrsinites*, *Rosa gymnocarpa*, *Linnaea borealis*, and *Vaccinium globulare*. *Clintonia uniflora* and *Tiarella trifoliata* are diagnostic for the h.t. and are joined by other high-constancy herbs such as *Disporum hookeri*, *Goodyera oblongifolia*, *Smilacina stellata*, and *Viola orbiculata*.

Mid- to late-seral stands of the TSHE/CLUN h.t. usually have extremely dense overstory canopies. This leads to a much-reduced light and moisture regime on the forest floor. Consequently, the herbaceous layer is sparse, sometimes to the apparent exclusion of any undergrowth vegetation. This condition will persist until the stand is opened by either natural or human-caused disturbance. Determination of h.t. for these stands requires careful investigation of what little understory vegetation may be present, and examining adjacent more open stands, or root rot pocket openings.

Aralia nudicaulis (ARNU) phase—The ARNU phase is found north of Coeur d'Alene, its major occurrence in northern Idaho being centered north and west of the Purcell Trench. It is restricted to elevations below 3,400 ft (1,040 m), flat to moderate slopes, and generally to toe-slopes, lower side slopes, or benches above a wet bottom area. This is the warmest, most moist phase of the TSHE/CLUN h.t.

Aralia nudicaulis is diagnostic at a canopy coverage of 1 percent or greater. Other commonly associated species besides *C. uniflora* and *Tiarella trifoliata* are *Cornus canadensis*, *L. borealis*, and *R. gymnocarpa*. *Thuja plicata* and *A. grandis* are the major seral trees in this phase. While some sites are too wet for other species to assume more than a subordinate role, *P. monticola*, *L. occidentalis*, and *Pseudotsuga* are capable of seral dominance and excellent growth where drainage is adequate.

Menziesia ferruginea (MEFE) phase—The MEFE phase is generally found between 4,300 and 5,000 ft (1,310 and 1,520 m) elevation with occasional occurrences on cold-air drainage slopes down to 3,000 ft (910 m). It normally occupies moderate to steep slopes with northwest exposures. This phase represents the cold, moist environments of the TSHE/CLUN h.t. Important seral dominants are *P. menziesii*, *A. grandis*, *L. occidentalis*, *P. monticola*, and *P. contorta*. In addition to these species, mature stands can also have a major component of *T. plicata*, *P. engelmannii*, and *A. lasiocarpa*. The understory vegetation is dominated by a shrub cover of *M. ferruginea* with *V. globulare*, *L. utahensis*, and/or *P. myrsinites* (fig. 8). The herbaceous layer may have high coverages of *Xerophyllum tenax*, *Arnica latifolia*, or *L. borealis*, along with *C. uniflora*, *Coptis occidentalis*, *S. stellata*, and *T. trifoliata*.

Xerophyllum tenax (XETE) phase—The XETE phase is found north of Coeur d'Alene at elevations ranging between 3,300 and 4,700 ft (1,000 and 1,433 m). This phase occurs on southeast to west aspects, flat to moderate slopes, and may be found on any landform or position. This is the driest of the higher elevation TSHE/CLUN phases. Major early seral tree species are *P. menziesii*, *L. occidentalis*, *P. contorta*, and *P. monticola*. Late seral and mature stands normally contain *A. grandis* and *T. plicata*. Although *Picea* and *A. lasiocarpa* are occasionally present, these sites are generally unfavorable for both. The understory is characterized by coverage of *Xerophyllum* in excess of 5 percent, with *V. globulare* often being abundant (fig. 9). *Clintonia uniflora* or *Coptis occidentalis* has at least sparse occurrence in all stands.

Figure 8—*Tsuga heterophylla/Clintonia uniflora* h.t.-*Menziesia ferruginea* phase on steep east-facing midslope (4,700 ft [1,430 m]) above Canuck Creek, Bonners Ferry Ranger District. The overstory is comprised of *T. heterophylla*, *Picea engelmannii*, *Abies lasiocarpa*, *Pinus monticola*, and *P. contorta*. The dense tall shrub layer is dominated by *M. ferruginea*, *Rhododendron albiflorum*, and *Alnus sinuata*. *Arnica latifolia* is the predominant forb with *C. uniflora* and *Tiarella trifoliata* common.

Figure 9—*Tsuga heterophylla/Clintonia uniflora* h.t.-*Xerophyllum tenax* phase on an old stream terrace (2,800 ft [850 m]) above East Fork Creek north of Clark Fork, ID. The overstory of this late-seral stage is dominated by *T. heterophylla*. The stand is unusual in that *Thuja* is outreproducing *T. heterophylla* and the moss coverage forms a nearly continuous carpet; this latter feature may account for the depauperate undergrowth in this rather open stand.

Clintonia uniflora (CLUN) phase—The CLUN phase is the driest, warmest phase of the TSHE/CLUN h.t. This phase can be found throughout the range of the *Tsuga* series on elevations ranging from 2,500 to 5,000 ft (760 to 1,520 m) and on all slopes, aspects, and landforms except wet bottoms. Early seral stands are usually dominated by *P. menziesii*, *L. occidentalis*, and/or *P. monticola*. Prior to site dominance by the climax species, these stands may have *A. grandis*, *A. lasiocarpa*, and/or *T. plicata* as late seral codominants. The CLUN phase is characterized by the absence of the more mesophytic species and is generally less species rich, with lower herbaceous coverages than associated phases. This phase has a low but consistent cover of *V. globulare*, *L. utahensis*, *P. myrsinites*, and/or *L. borealis* (fig 10). These species increase in cover on toe-slopes and lower gradient slopes, an indication of slightly more mesic conditions, usually grading into the TSHE/ASCA h.t.

Soils—Parent materials are mainly quartzite, siltite, sandstone, and metasediments with an ash cap, but gneiss, schist, gabbro, and loess are also found. Textures are slightly heavier than TSHE/GYDR and TSHE/ASCA soils, the predominant textural classes being silty-loam to silty clay-loam. The ARNU, MEFE, and XETE phases have 30 to 60 percent gravel, while the CLUN phase tends to have less than 10 percent gravel in its horizons. Average pH varies from 4.8 to 6.8. Total soil depths average between 12 and 26 inches (30 and 65 cm). Bare soil and rock usually do not occur on these sites. Average litter depth is 1.5 inches (4 cm).

Productivity/Management—Timber productivity is high to very high in the TSHE/CLUN h.t. (appendix F). Excellent height growth can be realized from *P. menziesii*, *L. occidentalis*, *A. grandis*, or *P. monticola*. The highest site indexes for *Pseudotsuga* are found on the CLUN phase: the best height growth for *Larix* is on the ARNU phase, and all species have appreciably reduced height growth on the XETE phase (appendix F).

Seedtree or very open shelterwood treatments on southeast to west slopes should result in good natural regeneration of *P. menziesii*, *L. occidentalis*, *A. grandis*, and *P. monticola*. On all other aspects, if an adequate seed source is present, clearcutting following seedfall should lead to abundant natural regeneration of these same species and even *T. heterophylla* (Boyd 1969). If the seed source is inadequate, planting in either of these aspect-dependent situations should prove successful. Shelterwood and selection treatments may be utilized if the desired regeneration species are *A. grandis*, *T. heterophylla*, *T. plicata*, *P. engelmannii*, or *A. lasiocarpa*. Stands with tall shrub components, particularly *Taxus brevifolia* and *V. globulare*, are important as moose, elk, and grizzly bear habitat.

Figure 10—*Tsuga heterophylla/Clintonia uniflora* h.t.-*Clintonia uniflora* phase on a midslope bench formation (3,750 ft [1,140 m]) northwest of the Sylvanite Ranger Station, Kootenai NF, MT. The center foreground, featuring a canopy gap occupied by *C. uniflora*, trailing *Rubus pedatus* and *Linnaea borealis*, and abundant moss, contrasts with the background where the depauperate undergrowth is typical of the closed canopy portion of this dense stand (460 ft^2/acre [105 m^2/ha]). Note *T. heterophylla* reproduction is confined to decaying logs.

Other Studies—The TSHE/CLUN h.t. is a subdivision of Daubenmire and Daubenmire's (1968) original *Tsuga/Pachistima myrsinites* h.t. Our ARNU and CLUN phases are essentially equivalent to syntaxa recognized by Pfister and others (1977) for northwestern Montana, Bell (1965) for southeastern British Columbia, and Lillybridge and Williams (1984) for the Colville NF. Our MEFE and XETE phases considerably overlap, both environmentally and compositionally, with the TSHE/*Rhododendron albiflorum* and TSHE/XETE associations of Lillybridge and Williams (1984). The several phases of our TSHE/CLUN h.t. are necessary to partition the broad environmental amplitude denoted by *C. uniflora* or *T. trifoliata* alone.

Tsuga heterophylla/Menziesia ferruginea h.t. (TSHE/MEFE; western hemlock/menziesia)

Distribution—TSHE/MEFE appears to be an incidental h.t. in northern Idaho, occurring above 5,000 ft (1,525 m) elevation in the Selkirk Range east of Priest Lake. The combination of environmental factors that restrict its occurrence to this location is unknown; we speculate this h.t. may be more extensive than our limited sample indicates. TSHE/MEFE tends to occupy sites warmer (gentle south-facing slopes and ridgetops) than those generally associated with *Menziesia ferruginea.*

Vegetation—*Abies lasiocarpa* and *Picea engelmannii* codominate with *Tsuga heterophylla* on seral stands of this h.t. Near-climax stands observed were almost pure *T. heterophylla,* with a very species-poor undergrowth consisting of *M. ferruginea, Xerophyllum tenax,* and *Vaccinium globulare* and scarcely more than trace amounts of *Pyrola secunda, Goodyera oblongifolia, Chimaphila umbellata,* and *Viola orbiculata.* TSHE/MEFE is floristically similar to TSME/MEFE-XETE, replacing *Tsuga mertensiana* by *T. heterophylla.* Further investigation may show this h.t. to be a slowly developing climax type on many acres currently supporting seral *A. lasiocarpa* and *P. engelmannii* communities.

Productivity/Management—We assume, lacking productivity data, that this h.t. approximates the timber productivity of ABLA/MEFE-XETE or TSME/MEFE-XETE. Management considerations should correspond to those of the two foregoing h.t.'s. The low species diversity in both overstory and undergrowth may indicate a non-productive site having serious regeneration problems.

Other Studies—This h.t. has not been previously described, but colder environments of the TSHE/*Rhododendron albiflorum* association of Lillybridge and Williams (1984) for the Colville NF have a comparable species composition.

Thuja plicata (THPL) Series

Distribution—In northern Idaho, *Thuja plicata* ranks second only to *Tsuga heterophylla* in its restrictive environmental requirements. *Thuja* can withstand both higher and lower temperatures, short periods of summer drought, and excess soil moisture better than *Tsuga.* Thus at the lower elevational transition of *T. heterophylla* h.t.'s, sites are usually dominated by *T. plicata*; and at the southern geographic limit of *Tsuga* (North Fork Clearwater River drainage) there is a transition to *Thuja* on upper-elevation moist sites. *Thuja* commonly occurs as far south as the Selway River drainage. An essentially direct relationship exists between the areal extent of THPL h.t.'s in northern Idaho and the western white pine type (Haig and others 1941).

The Daubenmires (1968) found codominance of *Thuja* and *Tsuga* to be typical of most wet sites, with no floristic differentiation evident in the undergrowth on sites that might eventually be dominated by one or the other of these tree species. On sites with high water tables or hummocky bottomlands within the *Tsuga* zone, we also found this to be the case. Only two stands, in almost one hundred samples of these wet environments, exhibited monospecific dominance by *T. heterophylla.* The apparent lack of *Tsuga* dominance may be an artifact of there being no stands at or near climax in our data base. This condition is so predominant throughout northern Idaho that we have, like the Daubenmires, combined *Thuja-* and *Tsuga-*dominated wet-site stands into the *Thuja* series.

In northern Idaho between the Selway River drainage and the Canadian border, *T. plicata* h.t.'s can be found on any aspect or slope and at elevations ranging from 1,500 to 5,500 ft (455 to 1,675 m). Although it occurs on all landforms, *Thuja* grows best on toe-slopes and bottomlands—areas with high soil moisture. *Thuja* occurs as scattered populations in eastern Washington (Daubenmire and Daubenmire 1968; Lillybridge and Williams 1984) and is well distributed along the northwestern border of Montana (Pfister and others 1977; Arno 1979).

Vegetation—In this series *Thuja plicata* is the climax dominant species; on very moist to wet sites *Tsuga heterophylla* may be a climax codominant. The presence of *Thuja* reproduction and all-age stand structure is not necessary for classification to this series. Extremes of temperature and soil moisture differences probably determine climax tree species on these sites. These factors seem to be particularly effective from germination to canopy closure. *Thuja* is a prolific seed producer and readily establishes regeneration on exposed mineral soil (Minore 1983). Due to the longevity of *Thuja* (500 to 1,000 years in northern Idaho), regeneration only needs to occur sporadically to maintain site dominance. Vegetative reproduction (layering) occurs in mature stands (Parker 1979), where reproduction of *Thuja* is often sparse, absent, or occasionally surpassed by less shade-tolerant species. Utilization by big game, snowshoe hares, and livestock is reported to remove significant amounts of *Thuja* reproduction (Tisdale 1960; Packee 1975; Habeck 1978; Mahoney 1981). Major seral tree species within the *Thuja plicata* series are *Pseudotsuga menziesii, Abies grandis,* and *Pinus monticola,* with *Picea engelmannii* on colder, wetter sites, and *Larix occidentalis* on drier sites. *Pinus ponderosa,* which is seldom important in this series, is conspicuously absent on wet sites, as is *Pseudotsuga.* Once an overstory canopy is developed, the understory climatic conditions of *Thuja* and *Tsuga* communities appear to be very similar. *Clintonia uniflora, Coptis occidentalis, Smilacina stellata, Disporum hookeri, Galium triflorum,* and *Viola orbiculata* are found on nearly every site within this series. Stratification of THPL habitat types is based on soil moisture and varying intensity of maritime climatic

influence, the dry to wet gradient being expressed by a change from *C. uniflora* h.t., to *Asarum caudatum* h.t., to *Gymnocarpium dryopteris* h.t., to *Adiantum pedatum* h.t., to *Athyrium filix-femina* h.t., to *Oplopanax horridum* h.t., respectively.

Productivity/Management—Although all tree species of northern Idaho except *Larix lyallii* can be found in at least minor amounts within the *T. plicata* zone, only *A. grandis*, *L. occidentalis*, *P. engelmannii*, *P. monticola*, *P. contorta*, *P. menziesii*, and *T. plicata* are capable of maintaining viable populations and high productivity on these sites. Within the mature stands sampled in northern Idaho, *P. engelmannii*, *P. monticola*, *Pseudotsuga*, and *Thuja* have their highest site indexes in this zone and are the major species on naturally regenerated sites. Competition for soil moisture and heavy browsing by snowshoe hares are found to be significant mortality factors in *Thuja* plantations (Mahoney 1981). Attempts at *P. ponderosa* plantations using offsite seed sources on sites apparently representing the cooler, more moist habitats of this series have been failures (Daubenmire 1961). Rehfeldt (1980) found for southern Idaho, and is finding in a current study for northern Idaho, considerable genetic diversity among and within *P. ponderosa* populations. The presence of relict *P. ponderosa* in the drier h.t.'s of the *Thuja* series indicates that plantings with local seed source progeny could be successful. A regeneration model (Ferguson and others 1986), based on silvical characteristics of Northern Rocky Mountain coniferous species and site data stratified by habitat type and treatment, has been developed as a submodel of the Stand Prognosis Model (Stage 1973).

Fire—Fire has been a major disturbance factor in the drier h.t.'s of the *Thuja* series. All stands sampled within the CLUN, ASCA, GYDR, and *Adiantum pedatum* h.t.'s had either fire-scarred trees or significant amounts of charcoal in the upper soil horizons. The wetter h.t.'s, *Oplopanax horridum* and *Athyrium filix-femina*, had little evidence of past fire, other than sporadic, cool, ground fires.

Other Studies—In the Northern Rocky Mountains, plant associations of the *Thuja* series have been described by Daubenmire (1952), Daubenmire and Daubenmire (1968), Pfister and others (1977), Steele (1971), Steele and others (1976), and Utzig and others (1983).

Thuja plicata/Oplopanax horridum h.t. (THPL/OPHO; western redcedar/devil's club)

Distribution—THPL/OPHO is found in small patches from the North Fork Clearwater River to the Canadian border. *Oplopanax* is normally found in bottoms having high water tables and cold-air drainage. It occurs at elevations ranging from 1,500 to 4,900 ft (460 to 1,495 m). This h.t. is generally associated with low gradient slopes on any aspect; landforms tend to be lower benches, valleys, and lower stream terraces. In the northwest portion of Boundary County, the THPL/OPHO h.t. occurs in mosaics with THPL/ATFI, THPL/CLUN-MEFE, and/or TSHE/CLUN-MEFE on steep, subirrigated, north-facing slopes.

Vegetation—*Oplopanax horridum*, a large, rhizomatous shrub with stout prickles, is the diagnostic species of this h.t., ranging from scattered individuals (at least 5 percent canopy coverage) to dense, impenetrable canopies. In addition to *Asarum caudatum*, *Clintonia uniflora*, *Tiarella trifoliata*, *Trillium ovatum*, and *Disporum hookeri*, these sites have high coverages of *Athyrium filix-femina*, *Circaea alpina*, *Gymnocarpium dryopteris*, *Senecio triangularis*, *Viola glabella*, and *Streptopus amplexifolius* (fig. 11). A warm, moist variant of this h.t. occurs on the north end of Dworshak Reservoir and up the North Fork Clearwater River to Isabella Creek in a coastal disjunct area (Steele 1971). *Thuja* and *Tsuga heterophylla*, either alone or as codominants, are the major seral and climax tree species on these sites. *Picea engelmannii* and *Abies grandis* occur sporadically as seral species on colder or higher elevation sites and warmer, lower elevation sites, respectively. Microsites with better drained soils occasionally support *Pinus monticola*.

Soils—Parent materials are quartzite and alluvial mixtures of metasediments, siltite, ash, and mica schist. Textures are fairly coarse, ranging from gravelly loamy sands to sandy loams, with gravel content of 40 to 50 percent in most horizons. The pH ranges from 4.5 to 6.0. Bare soil and rock usually do not occur on these sites. Average litter depth is 2 inches (5 cm).

Productivity/Management—The THPL/OPHO h.t. is a highly productive site for *Thuja*, *Tsuga heterophylla*, and *Picea* (appendix F). Site index is difficult to measure accurately due to the high percentage of suppressed and overmature trees present in natural stands. *Picea* and *Thuja* are the species best suited for toe-slopes and bottomlands. These two species, along with *Pinus monticola* on drier microsites, can be used to regenerate hillside mosaics. In all cases, though, great care must be exercised in logging these sites because water tables are near the surface. Bottomland or riparian sites should not be disturbed other than to salvage high-value trees or to remove high-risk trees. Salvage logging should not remove all dead and down logs because downed woody material serves as a seedbed for *Thuja* and *Tsuga* regeneration (Parker 1979). Hillside sites should also receive silvicultural treatments conducive to minimal soil disturbance. Natural regeneration by *Thuja* and *Tsuga* should be sufficient to revegetate sites; interplanting of *Picea* throughout the stand and *P. monticola* on drier microsites should be successful for establishing mixed-species stands. Major disturbance of this h.t. can result in total site occupancy by tall shrubs (*Acer glabrum*, *Alnus*, and *O. horridum*).

This h.t. has high value as wildlife habitat, offering high quantities of food, cover, and water. An unidentified wild ungulate, presumably elk, utilizes *Oplopanax* leaves and flower heads in late summer and fall, leaving some stands with only old, woody *Oplopanax* stems. Domestic livestock do not appear to use this h.t. to any extent.

Other Studies—This is the same h.t. as originally described by Daubenmire and Daubenmire (1968). It also corresponds to that described for Montana (Pfister and others 1977) and is comparable to interior British Columbia associations described by Bell (1965) and Utzig and others (1983).

Figure 11—*Thuja plicata/Oplopanax horridum* h.t. on a gently sloping north aspect (4,900 ft [1,495 m]) on the west side of Silver Mountain, Bonners Ferry Ranger District. Overstory is dominated by *T. plicata* and *Tsuga heterophylla* from 300 to 500 years in age. Undergrowth is dominated by patches of *O. horridum* interspersed with high coverages of ferns. Despite the sloping ground the water table is high; the characteristic gravelly soil is saturated to the surface throughout the growing season.

Thuja plicata/Athyrium filix-femina h.t. (THPL/ATFI; western redcedar/lady fern)

Distribution—The THPL/ATFI h.t. occurs commonly throughout the central and southern range of *Thuja*, with only sporadic locations north of Coeur d'Alene. Elevations range from 1,500 to 4,700 ft (460 to 1,430 m), slopes are less than 20 degrees, and all aspects other than southerly are represented. It occupies stream terraces, toe-slopes, and lower slope positions. This h.t. is slightly warmer than THPL/OPHO.

Vegetation—These sites are consistently very species rich. *Athyrium filix-femina*, with a coverage of at least 25 percent and a stature generally in excess of 3 ft (1 m), is diagnostic of this h.t. In addition to high constancy of *Adenocaulon bicolor*, *Asarum caudatum*, *Clintonia uniflora*, *Coptis occidentalis*, and *Tiarella trifoliata*, other commonly occurring high-moisture-dependent species are: *Senecio triangularis*, *Streptopus amplexifolius*, *Trautvetteria caroliniensis*, *Circaea alpina*, *Viola glabella*, and *Gymnocarpium dryopteris* (fig. 12). Incidental individuals or small patches of *Oplopanax horridum* may be found in this type, but they are restricted to microsites. Some sites have a high coverage of *Taxus brevifolia*, *Acer glabrum*, or *Alnus sinuata*, while other sites with better soil drainage support nearly pure stands of *Tsuga heterophylla*, indicating possibly a TSHE/ATFI h.t. *Tsuga* dominance does not occur on enough acres in northern Idaho to warrant delineating these communites from THPL/ATFI at this time.

Adiantum pedatum (ADPE) phase—The ADPE phase is found from the St. Joe River south to the Selway River. Elevations for this phase range from 1,500 to 3,700 ft (460 to 1,130 m); aspects vary from north to east. *Thuja plicata* and *Abies grandis* are the major tree species on these sites. *Adiantum pedatum* cover greater than 5 percent is diagnostic of this phase. This phase represents the warm, nutrient-rich portion of the THPL/ATFI h.t.

Athyrium filix-femina (ATFI) phase—The ATFI phase represents the modal condition for this h.t. Elevations generally range from 3,000 to 4,600 ft (910 to 1,400 m) on gentle slopes, with aspects from northwest to east. The major tree species are again *T. plicata* and *A. grandis*, but we also find seral *Pseudotsuga menziesii*, *Pinus monticola*, *Abies lasiocarpa*, and *Picea engelmannii* in this phase on suitable sites.

Soils—Parent materials are mainly quartzite, sandstone, and granitic, with some sites having metasediments, biotite, shale, and riverine or glacial alluvium. Textures are loamy sands to silt-loams, normally high in gravel content and very permeable. Soil pH ranges from 5.0 to 6.0;

Figure 12—*Thuja plicata/Athyrium filix-femina* h.t.-*A. filix-femina* phase on a gently sloping terrace (4,200 ft [1,280 m]) occurring north of Grass Mountain on the Bonners Ferry Ranger District. The stand is dominated by *T. plicata*, *Tsuga heterophylla*, and *Picea engelmannii*; *Abies lasiocarpa* is scattered. *Athyrium filix-femina* (considerably shorter than the 6-ft (2-m) heights attainable in this habitat type), *Dryopteris austriaca*, *Gymnocarpium dryopteris*, *Menziesia ferruginea* (in background), and *Rubus pedatus* dominate the undergrowth. Common herbaceous species are *Streptopus amplexifolius*, *Trautvetteria caroliniensis*, *Veratrum viride*, *Viola glabella*, and *Tiarella trifoliata*.

total soil depths range from 16 to 32 inches (40 to 80 cm). Bare soil and rock are usually not found on these sites; average litter depth is 2 inches (5 cm).

Productivity/Management—The THPL/ATFI h.t. is highly productive, the ADPE phase being slightly more productive than the ATFI phase (appendix F). Because this habitat type occurs on riparian terraces and adjacent toe-slope sites and on wet, highly compactible soils, disruptive logging practices are not recommended. Salvage logging should be limited to preserve downed woody material as a seedbed for *Thuja* and *Tsuga* regeneration (Parker 1979). These sites, particularly those with *T. brevifolia*, have extremely high value as big-game habitat throughout the year. Isolated old-growth stands have added value as recreational and botanical-interest areas.

Other Studies—Our THPL/ATFI h.t. is equivalent to that described by Daubenmire and Daubenmire (1968), Steele (1971), and Steele and others (1976). The ADPE phase we have described is equivalent to the ATFI phase of the THPL/ADPE h.t. of Steele and others (1976) and encompasses most of THPL/*Dryopteris* spp. h.t. described by Steele (1971).

Thuja plicata/Adiantum pedatum h.t. (THPL/ADPE; western redcedar/maidenhair fern)

Distribution—The distribution of the THPL/ADPE h.t. is restricted by the limited geographic occurrence of *Adiantum pedatum*, which in northern Idaho is found almost exclusively between the St. Joe and Selway Rivers. A few sites outside this area are known, but they are all small populations on microsites. Elevations for this h.t. are generally restricted to sites below 3,000 ft (910 m), although in the Selway River drainage examples of this h.t. occur as high as 4,700 ft (1,430 m). It is found on slopes ranging from 0 to 40 degrees and on all aspects except south. THPL/ADPE is normally located on moist mid to lower slopes and toe-slopes with good cold-air drainage, in a position slightly drier and upslope from THPL/ATFI.

Vegetation—Well-represented (≥5 percent) canopy cover of *A. pedatum* and much reduced coverages of wet-site species (*Trauvetteria caroliniensis, Senecio triangularis*, and *Gymnocarpium dryopteris*) indicators of the THPL/ATFI h.t. characterize this h.t (fig. 13). *Thuja plicata* is the major climax tree species; however, an occasional site will have enough *Tsuga heterophylla* regeneration to indicate that *Tsuga* may eventually dominate. *Abies grandis*

Figure 13—*Thuja plicata/Adiantum pedatum* h.t. on a northeast aspect of moderate slope (2,300 ft [700 m]) along Nylon Creek north of Dworshak Reservoir. The overstory is dominated by *T. plicata* with scattered *Abies grandis*, *Pseudotsuga menziesii*, and *Pinus monticola* still present as seral remnants. The diverse undergrowth is dominated by *A. pedatum* and *Polystichum munitum* with 15 shrub and 30 herbaceous species present in varying amounts.

is the most abundant seral species in older natural stands; reduced amounts of *Larix occidentalis*, *Pseudotsuga menziesii*, and *Pinus monticola* will also occur.

Stands found along the North Fork Clearwater River and the upper end of Dworshak Reservoir are much richer in species than the THPL/ADPE h.t. in general. This diversity is due to a long-persisting locally intensified expression of maritime environment, which has fostered disjunct, relict populations of coastal plant species (Steele 1971).

Soils—Parent materials are mainly metasediments, granitics, or mica schist, with occasional ash deposits, sandstone, and basalt. Textures range from loams to clay-loams, with small amounts of gravel. The pH values normally range from 5.1 to 6.3. Bare soil and rock do not usually occur; litter cover averages 1.5 inches (4 cm) in depth.

Productivity/Management—Site indexes are generally very high in this h.t. (appendix F). Both the small acreages and their close proximity to streams and riparian zones reduce the silvicultural options for this h.t. Salvage on these sites should be limited because downed woody material serves as a seedbed for *Thuja* and *Tsuga* regeneration. Disturbance to seasonally wet soils may lead to soil compaction or mass wasting. Big game may heavily use these sites, particularly during winter and spring.

Other Studies—The THPL/ADPE h.t. was originally described by Steele (1971) and Steele and others (1976). Sites that Steele classified as the ATFI phase of this h.t. we classified as belonging to the THPL/ATFI h.t., ADPE phase. Though similar, a THPL/ADPE association described by Bailey (1966) for the Oregon coast appears to be a different h.t.

Thuja plicata/Gymnocarpium dryopteris h.t. (THPL/GYDR; western redcedar/oak fern)

Distribution—Known locations of this h.t. for northern Idaho occur between the St. Joe and Selway River drainages. North of the St. Joe River, this h.t. is generally replaced by the TSHE/GYDR h.t. Elevations range from 3,200 to 4,500 ft (975 to 1,370 m). Slopes range from moderate to fairly steep (8 to 35 degrees), with mid to lower slope positions on predominantly west to northeast aspects. The THPL/GYDR h.t. is located on a moisture gradient between THPL/ATFI on the wet portion and THPL/ASCA on the drier sites.

Vegetation—This is the driest of northern Idaho plant associations characterized by a fern species, 5 percent or greater coverage of *Gymnocarpium* being diagnostic. *Athyrium filix-femina*, *Dryopteris* spp., or *Adiantum pedatum* may be present, but are restricted to wet microsites. *Abies grandis* and *Picea engelmannii* are the major late-seral tree species with *Pseudotsuga menziesii* and *Pinus monticola* occurring occasionally.

These are the wettest closed-canopy *Thuja plicata* sites that support appreciable shrub coverages. Shrub species with high constancy for this h.t. are *Acer glabrum*, *Lonicera utahensis*, *Rosa gymnocarpa*, *Linnaea borealis*, *Rubus parviflorus*, *Taxus brevifolia*, *Menziesia ferruginea*, and *Vaccinium globulare*. Commonly occurring forbs throughout this h.t. are *Asarum caudatum*, *Clintonia uniflora*, *Coptis occidentalis*, *Disporum hookeri*, *Smilacina stellata*, and *Tiarella trifoliata* (fig. 14).

Soils—Parent materials are mainly quartzite, sandstone, and schist, often mixed or overlain with volcanic ash. Textures range from gravelly loam to silty clay loam and pH values range from 5.4 to 6.4. Bare soil and rock are usually absent; litter depth averages 3 inches (8 cm).

Productivity/Management—The THPL/GYDR h.t. is highly productive for *A. grandis* and *P. engelmannii* and moderately productive for *P. monticola*, *P. menziesii*, and *T. plicata* (appendix F). Any of the above species with the proper silvicultural treatment should do well on these sites. Because of the richness and high growth rates of shrub species in this h.t., tree regeneration should be scheduled immediately following logging. Shrub and forb invasion can significantly impact reforestation through direct competition and/or attraction of large and small herbivores. Other major management considerations should be the proximity of these sites to riparian zones and potential compaction of seasonally saturated soils. Stands in this h.t. that have a high coverage of *T. brevifolia* may have high local value as moose winter habitat.

Other Studies—This h.t. has not been previously described. These sites would have been classified as *Thuja-Pachistima* by Daubenmire and Daubenmire (1968). Steele

Figure 14—*Thuja plicata/Gymnocarpium dryopteris* h.t. on a stream terrace bench (3,500 ft [1,070 m]) near Powell Campground on the Clearwater NF. The stand is multiple-aged evidenced by the presence of fire-scarred *Larix occidentalis* veterans, a population of even-aged mature *Abies grandis*, and vigorous saplings and seedlings of *T. plicata* and *Picea*. The characteristically diverse and dominant herbaceous layer has over 30 species; foremost in coverage are *G. dryopteris*, *Coptis occidentalis*, *Clintonia uniflora*, *Disporum hookeri*, and *Cornus canadensis*.

and others (1976) included GYDR as a minor phase of their THPL/ASCA h.t. on the Nez Perce NF.

Thuja plicata/Asarum caudatum h.t. (THPL/ASCA; western redcedar/wild ginger)

Distribution—The THPL/ASCA h.t. occurs commonly throughout the range of *Thuja plicata* in northern Idaho, from drainages in the Selway-Bitterroot Wilderness to the Canadian border. The normal elevational range is from 2,200 to 5,200 ft (670 to 1,590 m). It can be found on all aspects, landforms, and positions, with moderate slopes (8 to 25 degrees) predominating. THPL/ASCA occupies the warm, moist portion of the *Thuja* series, between the THPL/CLUN and THPL/GYDR h.t.'s.

Vegetation—A species-rich herbaceous layer is characteristic of this h.t., with the presence of *Asarum caudatum* scattered throughout the stand being diagnostic. When common (≥1 percent), *Viola glabella* is an equivalent indicator of this h.t. *Pteridium aquilinum* and *Polystichum munitum* commonly occur, with coverages to 5 percent (coverage much higher on open, disturbed sites); other fern species have not been recorded in greater than trace amounts. Other common forbs are *Clintonia uniflora, Coptis occidentalis, Disporum hookeri, Smilacina stellata,* and *Tiarella trifoliata.* The tree layer in seral stages often has *Pseudotsuga menziesii, Abies grandis, Larix occidentalis,* and *Pinus monticola,* with *Abies lasiocarpa* and *Picea engelmannii* present on colder sites.

Menziesia ferruginea (MEFE) phase—A shrub layer 3 to 6 ft (1 to 2 m) tall, having *M. ferruginea* well represented (≥5 percent), is diagnostic of this phase. *Vaccinium globulare, Lonicera utahensis, Rubus parviflora,* and *Acer glabrum* are commonly associated shrub species. This phase normally occurs above 4,000 ft (1,220 m) elevation on predominantly northerly aspects, on the coldest sites within the THPL/ASCA h.t.

Taxus brevifolia (TABR) phase—*Taxus brevifolia* as a dominant tall shrub or low tree layer, with canopy coverage of 5 percent or more, is diagnostic of this phase (fig. 15). This phase occurs from the St. Joe NF to northern portions of the Nez Perce NF on all slopes and landforms, but it is most prevalent on north and east aspects. The TABR phase occurs on the most moist, cool sites of the h.t., generally at elevations between 3,000 and 5,000 ft (910 to 1,525 m).

Figure 15—*Thuja plicata/Asarum caudatum* h.t.-*Taxus brevifolia* phase on a west-facing gentle backslope (4,700 ft [1,430 m]) on the Lower Fishhook Research Natural Area, St. Joe NF. Despite a very dense canopy of veteran (>300 years old) fire-scarred *T. plicata* and *Larix occidentalis*, *Taxus brevifolia* coverage is still abundant; *Menziesia ferruginea* and *Vaccinium globulare* coverages are much higher in canopy gaps. Though reduced in coverage the herbaceous component is moderately diverse and not depauperate (compare fig. 9).

Asarum caudatum (ASCA) phase—ASCA is the most common phase of THPL/ASCA, occurring on the warmest, driest sites within the h.t (fig. 16). The ASCA phase occurs over a wide range in aspect, slope, and position; however it tends to occur preferentially on northerly aspects at low elevations and on warmer southerly aspects at its upper elevational limits. The major seral tree species are *P. menziesii*, *A. grandis*, and *P. monticola*. *Aralia nudicaulis* is an occasional component of this phase, indicating potential for an ARNU phase as is found for THPL/CLUN in Montana (Pfister and others 1977). In northern Idaho, the ARNU phase occurs so sporadically that we have included it within the ASCA phase.

Soils—Parent materials are mainly granitic, quartzite, siltite, and sandstone, with some mixed loess and generally an ash cap or a loess-volcanic ash mix in the upper horizons. Textures are predominantly loams to silt-loams, with gravel contents of 5 to 30 percent. The TABR phase tends to have finer textured, more moist upper horizons than the other phases of this h.t. Soil pH ranges from 5.6 to 6.5; total depth ranges from 8 to 43 inches (20 to 110 cm), and average litter depth is 2 inches (5 cm).

Productivity/Management—THPL/ASCA is highly productive for timber. *Pseudotsuga menziesii* and *A. grandis* attain some of their highest site indexes on the ASCA and TABR phases, with significant reductions occurring for all species on the colder MEFE phase (appendix F). Selection and shelterwood cuts will favor *T. plicata* and *A. grandis* regeneration. *Pseudotsuga*, *L. occidentalis*, *Pinus monticola*, and *Pinus ponderosa* (ASCA phase only) should regenerate successfully from seedtree or artificial plantation treatments following overstory removal. Due to high productivity, these sites are susceptible to heavy shrub competition and damage from large herbivores and rodents during early stages of stand regeneration. A second precaution pertains to the potential for site degradation following stand entry on seasonally wet soils.

Old-growth stands of the TABR phase have high potential as late fall and winter moose habitat (Pierce 1983), particularly where this community replaces ABGR/ASCA-TABR in the areas north of the west-central Nez Perce NF.

Other Studies—THPL/ASCA describes a portion of the *Thuja-Pachistima* h.t. of Daubenmire and Daubenmire (1968), and has been partially described by Steele and others (1976) for the northern Nez Perce NF. East of the Cascade Range this h.t. appears to be restricted to the Pacific Maritime-influenced climatic zone of northern Idaho and northeastern Washington. Lillybridge and Williams (1984) have designated a THPL/ARNU association, the drier stands of which are floristically-environmentally very similar to our THPL/ASCA-ASCA.

Figure 16—*Thuja plicata/Asarum caudatum* h.t.-*Asarum caudatum* phase on a moderately sloping northwest aspect (4,600 ft [1,400 m]) on Moscow Mountain, Palouse Ranger District. The stand is pure old-growth *T. plicata* with no saplings or seedlings present. The shrub component is very reduced. Low forbs constitute the majority of the undergrowth with *Actaea rubra*, *Adenocaulon bicolor*, *Coptis occidentalis*, *Asarum caudatum*, and *Tiarella trifoliata* being most prevalent.

Thuja plicata/Clintonia uniflora h.t. (THPL/CLUN; western redcedar/queencup beadlily)

Distribution—The THPL/CLUN h.t. is the most common h.t. within the *Thuja plicata* series. It occurs throughout the range of *T. plicata* in northern Idaho, from drainages in the Selway-Bitterroot Wilderness to the Canadian border. The normal elevational range is between 2,200 and 4,800 ft (670 to 1,460 m), but it has been found as low as 1,500 ft (450 m) and as high as 5,500 ft (1,680 m). THPL/CLUN has a tendency to occur on the warmer southeast to northwest aspects, but does occur on all aspects. It is usually located on side slopes with moderate gradients (10 to 30 degrees). This h.t. represents the driest end of the environmental gradient in which *T. plicata* is the self-reproducing climax dominant species.

Vegetation—Self-sustaining populations of *T. plicata* and an understory containing *Clintonia uniflora*, *Coptis occidentalis*, or *Tiarella trifoliata* with very scarce representation of wet-site forbs or ferns are diagnostic of this h.t. *Asarum caudatum* and *Viola glabella*, if present, only occur on isolated moist microsites within the stand.

Menziesia ferruginea (MEFE) phase—This phase is characterized by dominance of midshrubs 3 ft (1 m tall)—*Menziesia ferruginea*, *Vaccinium globulare*, *Pachistima myrsinites*, and *Lonicera utahensis*, and on the coldest, wettest (or disturbed) sites, *Alnus sinuata*. Predominant seral tree species are *Pseudotsuga menziesii*, *Abies grandis*, *Larix occidentalis*, and *Picea engelmannii* (fig. 17). This phase normally occurs above 4,000 ft (1,220 m) elevation on northwest to east aspects, the cold, moist end of the environmental gradient encompassed by the THPL/CLUN h.t.

Taxus brevifolia (TABR) phase—The TABR phase is a minor component of the THPL/CLUN h.t., but very important as wildlife habitat. *Taxus* is well represented (≥5 percent) in the tall shrub to low tree layer on all aspects, slopes, and landforms and at elevations generally between 3,000 and 5,000 ft (915 and 1,525 m). Predominant seral tree species are *P. menziesii*, *A. grandis*, and *P. engelmannii*; *T. plicata* is capable of rapid postdisturbance colonization of these sites. This phase is centered on the Clearwater NF but may occur from the southern Coeur d'Alene NF to northern Nez Perce NF. The TABR phase represents the most moderate sites within THPL/CLUN but is slightly cooler and possibly drier than the TABR phase of THPL/ASCA.

Xerophyllum tenax (XETE) phase—The XETE phase is a minor component of the THPL/CLUN h.t. currently known only from the St. Joe drainage south to the Selway-Bitterroot Wilderness, but may occur elsewhere. Elevations range from 3,300 to 4,600 ft (1,010 to 1,400 m),

Figure 17—*Thuja plicata/Clintonia uniflora* h.t.-*Menziesia ferruginea* phase on a gentle north-facing slope approaching ridgetop (4,100 ft [1,250 m]) on Austin Ridge, Pierce Ranger District. This midseral stand is dominated by *Abies grandis* with abundant *T. plicata* regeneration in the understory. The undergrowth is very species rich (>40 species) with the shrub layer comprised primarily of *M. ferruginea* and *Vaccinium globulare*. *Xerophyllum tenax* dominates the herbaceous layer where *C. uniflora*, *Coptis occidentalis*, and *Cornus canadensis* are well represented.

with all aspects and slopes represented. This phase is characterized by a coverage of 5 percent or more of *Xerophyllum tenax* and a much reduced coverage of species characteristic of warm, moist environments, such as *C. uniflora*, *Disporum hookeri*, and *Galium triflorum*. Seral tree species in this phase are mostly *A. grandis* and *P. engelmannii*, with lesser amounts of *P. menziesii*, *Pinus monticola*, and *L. occidentalis*. The XETE phase represents the cold, dry environments within THPL/CLUN.

Clintonia uniflora (CLUN) phase—This is the most common phase of the THPL/CLUN h.t. occurring on the warmest, driest sites of the type. *Clintonia uniflora*, *Coptis occidentalis*, or *T. trifoliata* is always present, with very sparse or no representation of species diagnostic of the other three phases (fig. 18). The CLUN phase spans the elevational range for THPL/CLUN, occurring on all slopes and positions, with a tendency to occupy the warmer, drier, southeast to northwest aspects. Major seral tree species are *Pseudotsuga*, *A. grandis*, and *L. occidentalis*. *Pinus monticola* and *Pinus ponderosa* should do well on these sites. *Aralia nudicaulis* is an occasional component of this phase, indicating potential for an ARNU phase of this h.t. as is found in Montana (Pfister and others 1977). This occurrence appears so seldom in northern Idaho that we have included these communities within the CLUN phase of the THPL/CLUN h.t.

Soils—Parent materials are mostly granitic, quartzite, siltite, and sandstone, with some loess and ash caps. Textures are predominantly loams to silt-loams, with a gravel content of 5 to 35 percent. In the XETE phase the upper soil horizons are well to excessively drained. Soil pH ranges mostly between 5.6 and 6.6. Total soil depths are quite variable, ranging from 8 to 32 inches (20 to 80 cm). Bare soil and rock usually do not occur on these sites. Average litter depth is 2 inches (5 cm).

Productivity/Management—The THPL/CLUN h.t. is generally highly productive for timber. *Abies grandis* site indexes are nearly as high as in THPL/ASCA h.t., while *P. menziesii* and *L. occidentalis* have only slightly lower indexes than those measured on TSHE h.t.'s (appendix F). A significant reduction in site index occurs on the MEFE and XETE phases. The site index for *P. monticola* does not appear to be greatly affected by differing phases of THPL/CLUN, but its height growth appears to be significantly reduced from that measured on TSHE h.t.'s.

Selection and shelterwood cuts will favor *T. plicata* and *A. grandis* regeneration. *Pinus monticola*, *P. ponderosa* (CLUN phase only), *L. occidentalis*, and *P. menziesii* should regenerate successfully from seedtree treatments or artificial plantations following overstory removal. Old-growth stands of the TABR and MEFE phases, respectively, have potentially high value as late-fall/winter and

Figure 18—*Thuja plicata*/*Clintonia uniflora* h.t.-*C. uniflora* phase on a gentle east-facing slope (2,800 ft [850 m]) south of Bovill, Palouse Ranger District, Clearwater NF. Midseral stand codominated by *T. plicata* and *Abies grandis*. Undergrowth species diversity is high. *Vaccinium globulare* and *Linnaea borealis* dominate the shrub and subshrub layers, respectively. *Cornus canadensis*, *Coptis occidentalis*, *C. uniflora*, and *Smilacina stellata* are the dominant herbaceous species.

summer big game habitat, especially for moose (Pierce 1983).

Other Studies—This h.t. describes the driest environments of Daubenmire and Daubemire's (1968) *Thuja-Pachistima* h.t. The Montana THPL/CLUN h.t. and phases (Pfister and others 1977) coincide very well with those of northern Idaho, except that the *Aralia nudicaulis* phase in Montana occurs only sporadically in *T. plicata* stands in northern Idaho and appears to be seral to TSHE/CLUN-ARNU. Steele and others' (1976) THPL/CLUN h.t. for the Nez Perce NF corresponds directly to our THPL/CLUN-various phases. Lillybridge and Williams (1984) recognize a THPL/CLUN association which largely corresponds to our CLUN phase of THPL/CLUN. Their THPL/VACCI association is environmentally transitional between our XETE and CLUN phases of THPL/CLUN.

Tsuga mertensiana (TSME) Series

Distribution—The *Tsuga mertensiana* series has not been previously recognized in Idaho or Montana, having been encompassed within the *Abies lasiocarpa* series (Daubenmire and Daubenmire 1968; Pfister and others 1977). Our study has identified significant acreages where *T. mertensiana* is potentially the climax dominant, making its recognition worthwhile at a higher taxonomic level. The geographic distribution of *T. mertensiana* appears related to a strong maritime influence (Daubenmire and Daubenmire 1968; Habeck 1967), but it enigmatically occurs as discontinuous tracts within the subalpine zone occupied by *Abies lasiocarpa* and appears to be absent on the Kaniksu and most of the Kootenai NF's, where the inland-maritime influence ostensibly is strongest. Even where the TSME series is extensive it may be locally absent without an obvious environmental explanation.

The southern limit of the TSME series is the southern portion of the Middle Fork Clearwater River drainage. Scattered stands or individual trees of *T. mertensiana* have been found as far south as the White Sand Creek drainage of the Lochsa River. It extends northward as a rather continuous zone above 4,800 to 5,100 ft (1,460 to 1,555 m) in the Bitterroot, Clearwater, and Coeur d'Alene ranges to just south of the Clark Fork River drainage. The area just north of the Clark Fork River and west through the Purcell Trench represents the southernmost extension of continental glaciation in northern Idaho.

The series is encountered again in the Canadian Rockies, approximately 40 mi (66 km) north of the border (Arno and Hammerly 1984, pp. 223-226). Little (1971) shows limited acreages in the vicinity of Upper Priest Lake and Smith Peak (Kaniksu NF), but neither the authors nor the Daubenmires (1968) found these stands.

The current distribution of *T. mertensiana* in northern Idaho can be interpreted as a consequence of past glacial activity. Like the Canadian Rockies the mountains of northernmost Idaho were extensively glaciated but, unlike the valley locations of the Canadian Rockies, those of northern Idaho did not constitute refugia from which *T. mertensiana* was able to expand directly upslope following glacial recession. If *T. mertensiana* was not able, for whatever reasons, to keep pace with the glaciers', northward movement in the time of post-Pleistocene warming and drying (Mehringer 1985), then subsequent movement from more southerly refugia across intervening lowlands might have been rendered a physical improbability.

Along the border between the St. Joe and Clearwater NF's the *Tsuga mertensiana* series is replaced at lower elevations by the *T. heterophylla* series to the north and by the *Thuja plicata* series to the south. TSME types appear to grade to ABLA types over a broad environmental range within the TSME zone. The ABLA series sites do not appear environmentally different, but *T. mertensiana* may have a higher moisture requirement critical to establishment stages than do *A. lasiocarpa* or *Picea*. Alternatively, the explanation may be found in historical factors, specifically the vagaries of local fire histories and climate. *Tsuga mertensiana*, with its seed sources destroyed over large acreages, is simply slow to reforest sites where *A. lasiocarpa* has successfully established. (See McCune and Allen [1985] for possible explanations of why similar sites may fail to support similar, relatively stable forests.) Though uncommon, *T. mertensiana* may occur in frost pockets more than 2,000 ft (610 m) below its normal range. Consult the taxonomy section regarding apparent *T. mertensiana* × *T. heterophylla* intergrades.

Vegetation—As others (Daubenmire and Daubenmire 1968; Pfister and others 1977) have noted, the salient (and only aboveground) characteristic that distinguishes the *T. mertensiana* from the *A. lasiocarpa* series is the presence of *T. mertensiana*, reproducing successfully to become at least a climax codominant with the less shade-tolerant *A. lasiocarpa*. *Picea engelmannii* is the major seral species in more moderate environments, followed by, in decreasing order of importance, *Pinus contorta*, *Larix occidentalis*, *Pinus monticola*, and *Pseudotsuga menziesii*. The decreased seral importance of *P. contorta* in the TSME series, as opposed to similar environments in the ABLA series, may reflect greater stand ages in our data or possibly a stronger maritime climatic influence. Eighty percent of the stands in our data set were 120 years or older, a relatively old age for seral *P. contorta* stands in northern Idaho. Much of the Idaho-Montana Divide between Lolo Pass and Thompson Pass was severely burned between 1889 and 1919. The results in the TSME zone were vast acreages of seral stands (generally too young to sample, *P. contorta* the dominant and occasionally only tree species) and treeless areas. *Abies grandis* occurs sporadically as a minor seral or coclimax component on the warmest exposures. *Pinus albicaulis* is a seral component on upper subalpine and timberline habitats. (See ABLA series, Vegetation section for definition of terms relating to subalpine and timberline habitats.)

The undergrowth is dominated by *Menziesia ferruginea* on cold-moist exposures. *Vaccinium globulare* is well represented on all but the most severe sites. *Xerophyllum tenax* is well represented throughout the series—an indication that TSME sites are not as harsh (less windy, greater protective snowpack, and increased maritime influence) as the most stressful ones in the ABLA series. The most moderate sites support a relatively lush moist-site forb layer. Disturbance species other than *Epilobium angustifolium* are not extensive. The usual postdisturbance response is a delayed coverage increase of onsite species; however, *V. globulare* coverages may drop markedly and proportionately to the severity of disturbance on warm-dry exposures.

Productivity/Management—Lower elevation sites within the series have the highest timber potentials. In comparison with similar h.t.'s of adjacent areas and in absolute terms, the northern Idaho types show greater seral importance for *Picea* and *P. monticola* and reduced importance for *Pseudotsuga* and *P. contorta*. The reduced *P. contorta* and *L. occidentalis* importance may be spurious; where found, their growth potential was high. Site indexes for all species are remarkably similar to those of the ABLA series (appendix F).

Loss to heartrot, particularly *Echinodontium tinctorium*, is high in older stands (>100 years). Much of the old-growth *T. mertensiana* was cull, especially on moist or upper elevation sites.

Upper subalpine sites within the series have generally low timber potential and limited silvicultural opportunities; they are best suited to recreation, wildlife, and snowpack management.

Tsuga mertensiana/Streptopus amplexifolius h.t. (TSME/STAM; mountain hemlock/twisted stalk)

Distribution—This is a minor h.t. sampled only on the St. Joe and northern Clearwater NF's. TSME/STAM denotes the wettest sites in the series. It ranges from 5,000 to nearly 6,000 ft (1,525 to 1,830 m). Its occurrence is associated with seasonally saturated soils usually found on toe-slope positions and as riparian stringers (in tracts of less than 1 acre (0.4 ha)).

Vegetation—*Abies lasiocarpa* and *Picea* are often coclimax species with *Tsuga mertensiana*; all three species can rapidly recolonize these sites following disturbance. On lower elevation sites *Larix occidentalis*, *Pinus contorta*, and *P. monticola* may be well-represented seral components. Undergrowth vegetation strongly resembling that of ABLA/STAM is characterized by a variable assemblage of wet-site forbs (for example, in order of decreasing constancy, *Senecio triangularis*, *Ligusticum canbyi*, *Trautvetteria caroliniensis*, *Mitella breweri*, and *Veratrum viride*). *Menziesia ferruginea* and *Vaccinium globulare* create a dense shrub layer where tree canopy coverages are reduced.

Luzula hitchcockii (LUHI) phase—The LUHI phase represents high-elevation sites (>5,600 ft [1,710 m]), where snowpacks are deep and persistent. Sites are dominated by a variable composition of *T. mertensiana*, *A. lasiocarpa*, and *Picea*, all of which appear capable of maintaining populations in these open stands. The herbaceous layer, usually dominated by *Luzula hitchcockii*, is considerably less diverse and has less forb coverage than the MEFE phase. Adjacent sites with better drained soils support TSME/XETE or TSME/MEFE. Based on a limited sample and reconnaissance information, these sites are unfavorable for seral trees; only *P. contorta*, *P. monticola*, and *P. albicaulis* occur sporadically. Some areas have recently experienced heavy *P. albicaulis* mortality, possibly due to white pine blister rust (*Cronartium ribicola*). Extensive "ghost forests" typified by weathered large-diameter snags of *P. albicaulis* are most likely remnants of the 1911-42 mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreak (Ciesla and Furniss 1975).

Menziesia ferruginea (MEFE) phase—This phase represents lower elevation (<5,600 ft [1,710 m]) sites within the type. Though northerly slopes predominate, they experience earlier snowpack melt-off than those of the LUHI phase. TSME/STAM-MEFE usually grades to TSME/CLUN-MEFE or TSME/MEFE on better drained positions. Seral trees are apparently more common in this phase than the LUHI phase. *Pinus contorta* and *L. occidentalis* are the most important seral trees but are often absent or poorly represented because these sites can regenerate directly to the climax species or are excessively wet for *L. occidentalis* (fig. 19). Undergrowth composition follows the h.t. description.

Soils—Small sample size does not permit extensive characterization; preliminary results show rooting depths (to 27.5 inches [70 cm]) are relatively deep for the series and gravel content is high (average 30 percent), even in the upper profile (appendix D). The dominant factor, however, is a water table that influences the upper profile for at least a portion of the growing season.

Productivity/Management—Based on very limited data, site index values appear to be moderate to high (MEFE phase only), comparable to those of ABLA/STAM (appendix F). In terms of site index, *Picea* is the most productive species. Water tables, which rise following overstory removal, restrict timber management options. Where *Picea* has been selectively cut, the result has been pure *Abies-Tsuga* stands, with canopy gaps usually filled by dense undergrowth or climax tree reproduction.

Other Studies—Similar types have not been recognized for contiguous areas, but ecologically comparable units have been described for the Washington Cascades as TSME/*Streptopus roseus* (Henderson and Peter 1981), and southwestern British Columbia as *Tsugeto-Abieteto-Streptopetum* (Brooke 1965); both types are floristically much richer than that described here.

Figure 19—*Tsuga mertensiana/Streptopus amplexifolius* h.t.-*Menziesia ferruginea* phase on the Lewis and Clark Trail near Saddle Camp with a gentle easterly exposure (4,970 ft [1,515 m]). Characteristic for the h.t., the species other than *Picea*, *T. mertensiana*, and *Abies lasiocarpa* have not occupied this site since stand initiation. The typically robust shrub layer (*M. ferruginea* reaching 11 ft [3.5 m] and *Vaccinium globulare* taller than 5 ft [1.5 m]) obscures the rich undergrowth in which *Clintonia uniflora*, *Senecio triangularis*, *Arnica latifolia*, and *Trautvetteria caroliniensis* share dominance.

Tsuga mertensiana/Clintonia uniflora h.t. (TSME/CLUN; mountain hemlock/queencup beadlily)

Distribution—TSME/CLUN occupies relatively warm and moist sites within the *Tsuga mertensiana* series. It is extensive on the St. Joe, Coeur d'Alene, and northern Clearwater NF's. It occurs mainly between 4,800 and 5,700 ft (1,460 and 1,740 m) on all exposures. It was noted as low as 3,300 ft (1,010 m) with mature *Thuja plicata* or *Tsuga heterophylla* scattered in the stands, indicating communities transitional to THPL or TSHE/CLUN-MEFE. It normally grades to these types at its lower elevational limits on cold exposures. At its upper limits it grades to TSME/XETE or TSME/MEFE.

Vegetation—A wide variety of seral trees are adapted to these sites—the most important being *Picea engelmannii* and *Abies lasiocarpa*; both, but especially *Picea*, may persist as old-growth or minor climax components. Other sporadically occurring seral species are, in order of decreasing importance, *Pinus monticola*, *Larix occidentalis*, *Pinus contorta*, and *Pseudotsuga menziesii*.

A moderately rich forb assemblage sets this type apart from others in the TSME series; of those indicative of the h.t.—*Clintonia uniflora*, *Tiarella trifoliata*, and *Coptis occidentalis*—only *Coptis* is consistently well represented. *Vaccinium globulare* dominates the midshrub layer; *Xerophyllum tenax*, the forb layer. *Anemone piperi*, *Goodyera oblongifolia*, *Pyrola secunda*, *Trilium ovatum*, and *Viola orbiculata* are highly constant for the h.t.

Menziesia ferruginea (MEFE) phase—The MEFE phase occurs on west- through east-facing slopes, being most prevalent on cold, north-facing slopes from 4,700 to 5,700 ft (1,430 to 1,740 m). It moves far downslope along cold-air drainages and is transitional to TSME/MEFE on colder, possibly drier sites and TSME/CLUN-XETE or TSHE/CLUN-MEFE on warmer sites. *Picea* and *T. mertensiana* rapidly reforest these sites, with the early seral success of *P. monticola* and *L. occidentalis* much reduced by comparison. *Menziesia ferruginea* is abundant in the tall shrub (to 10 ft [3 m]) layer; *Vaccinium globulare* dominates a subordinate shrub layer. *Arnica latifolia* and *X. tenax* are the dominant herbs in a sometimes diverse assemblage (fig. 20).

Figure 20—*Tsuga mertensiana/Clintonia uniflora* h.t.-*Menziesia ferruginea* phase on a moderately steep north-facing slope (5,150 ft [1,570 m]) on Sheep Mountain Range, Clearwater NF. Widely spaced, large *Picea engelmannii* and *Tsuga mertensiana* create an open aspect typical of old-growth conditions. The undergrowth, dominated by *M. ferruginea* and *Vaccinium globulare*, is diverse with over 30 herbaceous species represented.

Xerophyllum tenax (XETE) phase—The XETE phase constitutes the relatively warm, moist portion of the h.t., occurring predominantly on southerly slopes and occasionally benchlands. The observed elevational range was 4,750 to 5,600 ft (1,450 to 1,710 m). It grades to TSME/XETE on drier, colder exposures, to TSME/CLUN-MEFE on colder sites, or to the THPL and TSHE series on warmer sites. *Picea* is the most important seral species and may persist as a coclimax dominant. Limited samples permit only a crude ranking of the other seral species; apparently *Pseudotsuga* is more successful here than elsewhere in the series, followed by *P. contorta*, *P. monticola*, and *Larix*. Undergrowth composition corresponds to the h.t. description (fig. 21).

Soils—Parent materials are predominantly granitics and quartzite but include other noncalcareous sedimentary rocks (appendix D); the upper horizons are all strongly ash influenced to a depth of at least 14 inches (35 cm) (average 17 inches [44 cm]). Restrictive layers have not been noted, and exposed soil and rock are negligible. Surface soils are, without exception, fine textured, ranging from loams to silty clay loams; subsurface soils are also dominated by loams and gravel content increases markedly only in the lower B and C horizons (to an average of 20 percent). Effective rooting depths average 19 inches (49 cm), the deepest within the series. Both surface and subsurface horizons are mostly moderately acidic (surface pH averages 5.8, 4.9 to 6.3; subsurface 5.7, 5.2 to 6.0). Insufficient data exist to distinguish phase differences (between MEFE and XETE), though the XETE phase does trend to shallower rooting depths.

Productivity/Management—Based on limited site index data TSME/CLUN appears to be the most productive of the TSME series h.t.'s, similar on a species-by-species comparison with ABLA/CLUN for northern Idaho (appendix F) or western Montana (Pfister and others 1977). Given that seral tree species are often minor components of mature stands as well as on clearcuts, silvicultural prescriptions should address strategies for the establishment of more rapidly growing intolerant species. Other implications and prescriptions follow those for the corresponding phases of ABLA/CLUN.

Other Studies—This type has not been previously described, but data sets of Daubenmire and Daubenmire (1968) and Pfister and others (1977) contain a small percentage of stands fitting this h.t. In the Cascades and Olympic Mountains where maritime climatic regimes prevail, Hemstrom and others (1982) and Henderson and Peter (1981) have described TSME types, portions of which are vegetatively very similar to TSME/CLUN.

Figure 21—*Tsuga mertensiana/Clintonia uniflora* h.t.-*Xerophyllum tenax* phase just east of Mullan Pass, ID, on a gentle south-facing slope (4,780 ft [1,460 m]). The infamous 1910 Burn devastated this area. *Abies lasiocarpa* and *T. mertensiana* are just entering the sapling size class under the 60- to 65-year-old canopy dominated by *Pinus contorta* and *Larix occidentalis*. *Vaccinium globulare* and *X. tenax* dominate the undergrowth in which *Pachistima myrsinites* and *Calamagrostis rubescens* are well represented and typical of early to midseral conditions.

Tsuga mertensiana/Menziesia ferruginea h.t. (TSME/MEFE; mountain hemlock/menziesia)

Distribution—This h.t. is important on the St. Joe, Coeur d'Alene, and northern portion of the Clearwater NF's. TSME/MEFE typifies sites colder than TSME/CLUN, which it merges with below; it is found between 5,100 and 6,100 ft (1,550 and 1,860 m), characteristically on the highest northerly slopes and protected portions of ridgeline benches. It grades to TSME/XETE and ABLA/XETE on warmer, drier exposures and to TSME/CLUN on warmer exposures.

Vegetation—The relative climatic severity of these upper subalpine sites is reflected in a reduced importance of seral *Pseudotsuga menziesii*, *Pinus monticola*, and *Larix occidentalis*. *Pinus contorta* and *Picea engelmannii* are inexplicably poorly represented compared to their representation in ABLA/MEFE, possibly as an artifact of small sample size and older stands, or because *Abies lasiocarpa* and *T. mertensiana* rapidly restock these sites following disturbance (Fiedler 1980).

A tall, dense *Menziesia* layer dominates the undergrowth, and *Xerophyllum tenax* is well represented in the forb layer, which is notably depauperate compared to more moderate subalpine h.t.'s. Of other species present, only *Vaccinium globulare* and *V. scoparium* exceed 50 percent constancy, and their coverage is phase dependent.

Luzula hitchcockii (LUHI) phase—This phase is not common, being present on only the highest elevations, generally above 5,700 ft (1,740 m) on north-facing slopes to ridgetop benchlands. Here snowpacks persist well into the growing season. *Abies lasiocarpa* and *Tsuga mertensiana* are usually codominant, and *Picea, P. contorta*, and *L. occidentalis* are sporadically distributed seral species. Common coverages of *Luzula hitchcockii* or *Phyllodoce empetriformis* are diagnostic for the phase and under the characteristically open canopy structure they often become abundant (fig. 22). Species diversity and the size and importance of *V. globulare* are generally much less than within the XETE phase, whereas *V. scoparium* and *Rhododendron albiflorum* increase in importance.

Figure 22—*Tsuga mertensiana/Menziesia ferruginea* h.t.-*Luzula hitchcockii* phase on a moderately steep north-facing slope (6,010 ft [1,830 m]) near a ridgecrest above Papoose Saddle on the Clearwater NF. Stand is still in early phenological state in this mid-July photo showing the dominant *M. ferruginea* just leafing out; snow patches have just melted off the *L. hitchcockii* patches near the meter pole. Dominants in the overstory and understory are, respectively, *Abies lasiocarpa* and *T. mertensiana.*

Xerophyllum tenax (XETE) phase—XETE is the common phase within the type, occurring from 5,100 to 5,800 ft (1,550 to 1,770 m) primarily on northerly exposures. It grades to TSME/MEFE-LUHI or TSME/XETE-VASC at higher elevations, TSME/CLUN-MEFE at lower elevations, or TSME/XETE or ABLA/XETE on warmer exposures. Tree distribution follows the h.t. description. Undergrowth is distinguished by greater forb diversity and constancy than that of the LUHI phase; consistently present are *Goodyera oblongifolia, Viola orbiculata,* and *Pyrola secunda. Vaccinium globulare* is abundant in more open stands (fig. 23).

Soils—Soils were developed primarily from quartzite, granitics, and gneiss, with all profiles having a moderate ash influence to about 10 inches (25 cm) (appendix D). Rooting depth in the LUHI phase averaged only 13 inches (33 cm) and is expected to be deeper in the XETE phase. In both phases, surface horizons are dominantly nongravelly whereas subsoils usually contain a high percentage of gravel. The nongravel fractions are loams to silty clay loams. No restrictive layers were found, but rooting depths usually dramatically decrease where rock content increases. Surface soils in the LUHI phase are extremely acidic (average 4.2, range of 4.0 to 5.2), whereas subsoil horizons are mostly strongly acidic (5.5, 5.0 to 5.9); the XETE phase averages more than one pH unit higher than LUHI for surface soils and one-half unit higher for the subsurface.

Figure 23—*Tsuga mertensiana/Menziesia ferruginea* h.t.-*Xerophyllum tenax* phase in the vicinity of Little Joe Pass, ID, on a gentle northwest slope at relatively high elevation (6,180 ft [1,885 m]) for the phase. Overstory dominance in the 140-year-old stand is shared among *Picea engelmannii*, *Abies lasiocarpa*, and *T. mertensiana* with no indication intolerant tree species have occupied the site since stand initiation. Presence of *Vaccinium scoparium* and *Luzula hitchcockii* and low stature of *Vaccinium globulare* indicate this site is tending toward harsh conditions for the type.

Productivity/Management—Analysis of limited site index data suggests that productivity decreases along the gradient of increasing site severity, from moderate to high in the XETE phase to low to moderate in the LUHI phase (appendix F). Management considerations should correspond to those of the comparable ABLA series h.t.'s. Especially noteworthy is the relative lack of seral tree species in both mature stands and following clearcutting (with various postharvest treatments).

Other Studies—Daubenmire and Daubenmire (1968) first described this h.t. for northern Idaho; it was confirmed for extreme western Montana by Pfister and others (1977) and Habeck (1967). Pfister and others (1977) defined TSME/MEFE more narrowly, including stands with *L. hitchcockii* present in TSME/LUHI-MEFE. We saw little indication that these stands were approaching a timberline condition typical of TSME/LUHI-MEFE, although they are frequently quite open, with shrub-dominated parks between tree clumps.

Tsuga mertensiana/Xerophyllum tenax h.t. (TSME/XETE; mountain hemlock/beargrass)

Distribution—TSME/XETE is an important type on the St. Joe and Coeur d'Alene NF's and the Clearwater NF north of the Clearwater and Lochsa Rivers. It occurs from 5,100 to 6,350 ft (1,550 to 1,940 m) on upper slopes and ridgelines, with all but northern aspects represented. It grades to TSME/MEFE on cooler or more protected sites and to TSME/CLUN-XETE on warmer sites.

Vegetation—The tree layer of these sites is usually dominated in all successional stages by *Tsuga mertensiana* and *Abies lasiocarpa*. Seral species, especially *Pinus contorta* and *Picea engelmannii*, are seemingly less successful here than in the comparable type in Montana or in ABLA/XETE. *Pinus albicaulis* may be locally important as a long-lived seral component. Undergrowth is very similar to ABLA/XETE; *Xerophyllum tenax* is dominant and other components vary by phase.

Luzula hitchcockii (LUHI) phase—This phase occupies cold, relatively high-elevation (6,000 to 6,350 ft [1,830 to 1,940 m]) sites, which because of their position in the landscape or low slope angles, accumulate deep, late-persisting snowpacks. *Luzula hitchcockii* and *Phyllodoce empetriformis* are indicative of these conditions (and the phase) (fig. 24). *Picea*, on protected sites, and *P. contorta* and *Larix occidentalis* are minor seral species. *Vaccinium scoparium* exhibits increased coverages relative to other types and phases in the series, whereas *Vaccinium globulare* occurs sporadically and generally is not a shrub layer dominant.

Vaccinium scoparium (VASC) phase—The VASC phase denotes upper elevations (5,700 to 6,500 ft [1,750 to 1,980 m]) and environmentally stressful conditions within TSME/XETE. It usually occurs on the upper third of southerly facing slopes. *Pinus contorta* dominates seral stands and *Pinus monticola*, *L. occidentalis*, and *Pseudotsuga menziesii* are represented on the more protected sites. *Pinus albicaulis* is a minor seral component at higher elevations. Stands are characteristically open (tree canopy coverages generally not exceeding 80 percent) which favors the development of dense patches of *V. scoparium* interspersed with clumps of *X. tenax* and *Carex geyeri*. With high tree canopy coverages, *V. scoparium* is markedly reduced in cover, and in extreme cases canopy gaps must be examined to reveal potential of the site to support *V. scoparium*. The undergrowth is notably depauperate, averaging only eight species per plot.

Xerophyllum tenax (XETE) phase—The XETE phase occurs from 5,100 to 6,000 ft (1,550 to 1,830 m), predominantly on southern exposures. It grades to TSME/CLUN-XETE below and to TSME/XETE-LUHI or XETE-VASC above. *Larix occidentalis*, *P. monticola*, *P. contorta*, *Pseudotsuga*, and *Picea* were noted in reconnaissance to be locally important seral species; our sample plots reflect a

Figure 24—*Tsuga mertensiana/Xerophyllum tenax* h.t.-*Luzula hitchcockii* phase on a high ridgecrest (6,480 ft [1,975 m]) along the Lewis and Clark Trail east of Indian Post Office, Clearwater NF. All-aged *Abies lasiocarpa* and *T. mertensiana* dominate the site, with *Pinus contorta* remnants scattered. *Phyllodoce empetriformis* and *L. hitchcockii* form a mosaic of dense patches; the open ground denotes areas of late-persisting snowpack.

notable scarcity of these species. Species diversity in all layers is higher here than in the LUHI phase, but not nearly that of TSME/CLUN-XETE. *Vaccinium globulare* dominates the shrub layer in which *Sorbus scopulina* and *V. scoparium* are highly constant but low in coverage. *Calamagrostis rubescens* and *C. geyeri* are capable of dominating early seral stages and persisting in abundance in open, mature (80 years plus) stands.

Soils—Parent materials consisted of metamorphosed granitic and sedimentary rocks (appendix D). Ash and loess influenced all profiles to a variable degree. Restrictive layers were not encountered; exposed soil and rock, generally not exceeding 5 percent coverage, occurred in over 75 percent of the stands. Soil textures are predominantly loams and silt loams; however, coarser soils are found more frequently in this than other TSME h.t.'s. Rooting depth varies by phase, VASC and LUHI averaging 14 inches (36 cm) and XETE 18 inches (46 cm). Gravel content averages 17 percent in the upper profile and increases greatly with increasing depth, usually with a 20 to 50 percent increase from the B horizons to the B/C or C horizons, at a depth that corresponds approximately to the depth of rooting. In all phases soil reactions of the upper profile are strongly to very strongly acidic, decreasing to mostly moderately to slightly acidic with increasing depth.

Productivity/Management—Based on limited data, TSME/XETE site indexes differ according to phase; XETE-XETE timber productivity appears comparable to that of ABLA/XETE-VAGL (appendix F). The more limiting environments of VASC and LUHI phases register lower site index values, comparable to those of ABLA/XETE-VASC or ABLA/XETE-LUHI (appendix F). The reduced importance of typical seral species (*P. contorta* and *L. occidentalis*) is notable and could have significant silvicultural implications. This observation must be further evaluated over a greater area and for younger stands. The results of Fiedler's (1980) study may be cautiously extrapolated to this type (see ABLA/XETE); among the salient points is the need for scarification to achieve rapid reforestation by seral species. High coverages of *C. rubescens* and *C. geyeri*, which may result following overstory removal, retard seedling establishment.

Other Studies—Daubenmire and Daubenmire (1968) first described this type, without phase distinctions. Pfister and others (1977) also recognized this h.t., but any stands containing *Luzula hitchcockii* were placed in TSME/LUHI-VASC. Plant associations very similar to TSME/XETE have been described for relatively dry subalpine sites in the Cascade Range (Hemstrom and others 1982; Henderson and Peter 1981).

Tsuga mertensiana/Luzula hitchcockii h.t. (TSME/LUHI; mountain hemlock/smooth woodrush)

Distribution/Vegetation—TSME/LUHI is an incidental type found as small patches at the uppermost elevations and denoting the most severe environments within the TSME series. It generally occurs on lee slope positions where snowpack is deep and late persisting, as indicated by the nearly monospecific dominance of *Luzula hitchcockii*. Clusters of wind- and snowpack-deformed *Tsuga mertensiana* and *Abies lasiocarpa* codominate. The density of *Pinus albicaulis* snags shows it can be an important seral tree depending on the vicissitudes of stand development. The generally small diameter of the dead trees and complete demise of whole stands point to white pine blister rust (*Cronartium ribicola*) as the responsible agent. The possibility of mortality due to mountain pine beetle (*Dendroctonus ponderosae* Hopkins) can be evaluated by examining debarked boles for the outlines of vertical egg galleries etched into the sapwood (Ciesla and Furniss 1975).

Productivity/Management—No data exist here, but the similarity to ABLA/LUHI in site factors and vegetation argues that these sites hold marginal timber-producing potential. Because these sites often border mountain grasslands and herb-dominated meadows, they are of value as wildlife cover. Generally low productivity, inaccessibility, and fragility of these sites suggest minimal disturbance.

Other Studies—Pfister and others (1977) described TSME/LUHI from the Montana-Idaho border area, but their h.t. corresponds to VASC and LUHI phases within our TSME/MEFE and TSME/XETE h.t.'s. Neither Pfister and others (1977) nor Daubenmire and Daubenmire (1968) described TSME series sites as severe as described herein.

Abies lasiocarpa (ABLA) Series

Distribution—The *Abies lasiocarpa* series occurs as a broad subalpine zone on all National Forests in northern Idaho, but the series is greatly reduced in occurrence from the northern portion of the Middle Fork Clearwater River drainage to the southern portion of the Coeur d'Alene NF, where it is displaced by the *Tsuga mertensiana* series. On the southern Clearwater and Nez Perce NF's, the lower limits of the ABLA series considerably overlap the upper limits of the *Abies grandis*, or rarely the *Pseudotsuga menziesii* series.

Field separation of the *A. grandis* and *A. lasiocarpa* series is made difficult by this distributional overlap. These series are distinguished on the basis of relative reproductive success, projecting the more numerous species to climax dominance. Consequently, either species may occur as a seral or climax component of the opposing series. In younger seral stands or where relative reproductive success is equivalent or difficult to ascertain, we have favored *A. lasiocarpa* in the key; most evidence (Minore 1979) indicates *A. lasiocarpa* to be more shade tolerant. *Abies lasiocarpa* presence in the *A. grandis* series is indicative of somewhat colder and less productive environments. If a choice of series appears completely arbitrary, a more conservative approach would be to select the *A. lasiocarpa* series.

Northward, the ABLA series merges downslope with the *Thuja plicata* or *Tsuga heterophylla* series. The ecotone from the ABLA series to any of the above-mentioned series indicates low temperatures and shortened growing seasons critical to reproduction and establishment (Daubenmire 1956).

The areal extent of the ABLA series in northern Idaho, especially when contrasted to Montana or central Idaho, is limited due to a scarcity of high elevations and a climate more moderate than Montana or central Idaho.

Habitat types of the ABLA series extend to the alpine timberline, where on the highest peaks they are bordered by small tundralike herb communities, extensive grassy balds, or heaths dominated by the ericaceous subshrubs *Cassiope mertensiana* and *Phyllodoce empetriformis*. At mid to upper elevations of the ABLA series, dry, grassy parks or balds of southerly exposures, and moist meadows of northerly slopes, are caused by a combination of wind redistribution of snow from southerly to northerly aspects, shallow, rocky soils, and bedrock fractured so as to permit water percolation beyond tree rooting depths (Root and Habeck 1972). The dry, grassy parks are dominated by variable combinations of *Festuca idahoensis, Agropyron spicatum, Festuca viridula,* and *Arenaria capillaris,* whereas the late-melt areas ("snow glade" community type) (Billings 1969) support alpine herbs such as *Carex nigricans, Carex tolmiei, Deschampsia atropurpurea, Deschampsia cespitosa, Sibbaldia procumbens,* etc. (Daubenmire and Daubenmire 1968; Daubenmire 1981).

Pfister and others (1977), following Löve (1970), have delineated three elevational-ecological subdivisions of the ABLA series that reflect increasing climatic severity: (1) Lower subalpine forest h.t.'s are those sufficiently warm to support *Pseudotsuga, Larix occidentalis,* or *Pinus monticola*. *Picea* is the major seral species on moist to wet h.t.'s. In northern Idaho, this category is compressed to 600 to 1,000 vertical ft (180 to 305 m) on the Kaniksu and Coeur d'Alene NF's but expands to cover from 1,000 to 2,000 vertical ft (305 to 610 m) on the Nez Perce NF. (2) Upper subalpine forest h.t.'s are those above the climatic limits of *Pseudotsuga, L. occidentalis,* and *P. monticola*. These sites usually support *Luzula hitchcockii* in the undergrowth, and *Pinus albicaulis* is a common, sometimes persistent, seral tree. *Abies lasiocarpa* growth is slow, often taking 200+ years to reach full height of only 50 to 70 ft (15 to 22 m). *Picea engelmannii* is a major, persistent, seral component on all sites, whereas *Pinus contorta* is a short-lived, major seral species characteristic of drier, warmer sites. This middle zone is of limited vertical extent, usually less than 500 ft (150 m) on the Kaniksu NF and 800 ft (245 m) on the Nez Perce NF. (3) Timberline habitat types constitute the transition between continuous forest (tree line) and alpine, tundralike conditions. The uppermost portion of this zone is krummholz ("scrub line") (Arno 1966). This zone is conveniently indicated by the stunting of *A. lasiocarpa* and *Picea*, their mature heights generally not exceeding, respectively, 50 and 65 ft (15 and 20 m). Only *P. albicaulis, P. engelmannii, A. lasiocarpa,* and *Larix lyallii* are capable of establishing here, beyond the climatic limits of *P. contorta, Pseudotsuga, A. grandis,* and even *Menziesia ferruginea*. These sites are apparently of very limited extent in northern Idaho. Three groups of timberline h.t.'s are recognized: PIAL-ABLA, ABLA-LALY, and ABLA/LUHI. In Montana, these habitats are primarily temperature controlled (macroclimate), whereas in northern Idaho, drying winds, heavy snow accumulations, or excessive subsurface rockiness may result in the same community response.

Vegetation—*Picea engelmannii* is the major seral species on moist-cool sites. It is progressively reduced in importance on colder and/or drier sites where the importance of *A. lasiocarpa* and seral *P. contorta* is concomitantly increased. *Pinus contorta* tends to be quickly replaced on productive sites but is more persistent on upper subalpine sites. *Pinus ponderosa* is notably rare in the series. *Pseudotsuga* is best represented on lower subalpine types, developing significant coverages on warmer slopes with free drainage. *Larix occidentalis* and *P. monticola* are generally less important than other seral species, but given the proper circumstances, can produce nearly pure, long-persisting, even-aged stands.

Undergrowth varies from graminoid-dominated (open parklike sites) to dense tall shrubs; and from lush forbs (wet sites) to a depauperate herbaceous component (dry sites). Species diversity is progressively reduced from lower to upper subalpine to timberline h.t.'s. Because few species are adapted to sites with a short growing season and low temperatures, revegetation and recovery proceed slowly following disturbance. Except for *Pteridium aquilinum, Calamagrostis rubescens, Epilobium angustifolium, Rudbeckia occidentalis,* and *Alnus sinuata*, which may increase markedly following fire or logging, indicators of disturbance are uncommon. For central Idaho, Steele and others (1981) cite *Polygonum phytolaccaefolium, Spraguea umbellata*, high coverages of *Penstemon attenuatus* and *Potentilla glandulosa*, and, on wet sites, *Veratrum viride* as indicators of disturbance, principally grazing. Within northern Idaho the same disturbance patterns have been noted only on the southwestern Nez Perce NF, especially in the Seven Devils Range.

Fire—Nearly pure stands of fire-generated *P. contorta* occupy extensive areas on all northern Idaho forests but are most common in the southern portion of the study area. Locally, *L. occidentalis* occurs in a similar pattern of pure, even-aged stands on old burns. Stand-replacing wildfires have burned vast expanses and, coupled with subsequent burns, have locally nearly eliminated the seed sources of climax species and delayed succession to intolerant conifers. Another, more common result of stand-replacing wildfire is monospecific stands which are frequently overstocked and potential centers for disease and insect epidemics. In the wetter portions of the ABLA series, fires are infrequent (fire-free intervals of 100 years or longer) and usually stand-replacing (Arno 1980). Harvesting can produce a mosaic of smaller, even-aged stands or stands of varied ages and will thus reduce the potential for natural epidemics through removal of fuels and breeding environments.

Productivity/Management—Lower subalpine sites have the greatest timber potential followed by the upper subalpine and lastly the noncommercial timberline environments (appendix F). These upper elevation sites are better suited for management that emphasizes recreation, wildlife, and watershed values.

Pinus contorta, Picea, L. occidentalis, and *P. monticola* are productive and can be successfully regenerated in the lower subalpine zone. *Picea* is susceptible to windthrow on partial cuts, especially where water tables are high. *Pseudotsuga* is moderately to highly productive, and the

highest probability of successful silvicultural manipulation occurs on lower subalpine sites. The notable lack of success with planted *P. ponderosa* in the ABLA series corresponds to the observation that it rarely occurs naturally within the series.

Pertinent studies of silvicultural manipulation and secondary succession include Roe and DeJarnette (1965), Boyd and Deitschman (1969), Basile and Jensen (1971), Alexander (1973), Fiedler (1980, 1982), Arno and Simmerman (1982), and McCaughey and Schmidt (1982).

Abies lasiocarpa/Calamagrostis canadensis h.t. (ABLA/CACA; subalpine fir/bluejoint)

Distribution—ABLA/CACA is a minor type in northern Idaho, found mostly south of the Middle Fork of the Clearwater River drainage; its presence only in the south of the study area may be attributable to a stronger continental climatic regime (see Other Studies section). ABLA/CACA occurs at lower to middle elevations of the subalpine zone (5,100 to 7,100 ft [1,555 to 2,165 m]) but may extend to 7,500 ft (2,290 m); small frost pocket locations were noted as low as 3,900 ft (1,190 m). It occupies stream terraces, adjacent to *Carex*- and *Juncus*-dominated wet meadows (and *Salix* spp.- and *Ledum glandulosum*-dominated swamps), toe-slopes with seeps, and sites with perched water tables—in general, poorly drained, seasonally saturated sites. Because of the distinctive site conditions, ABLA/CACA is invariably confined to small areas. It borders a broad variety of h.t.'s, from ABLA/XETE-VASC to ABGR/CLUN-CLUN.

Vegetation—The saturated soils and cool microclimate limit conifer establishment to a few species. *Pinus contorta* and *Picea engelmannii* are the major seral species, with *Picea* persisting as a climax codominant with *Abies lasiocarpa. Larix occidentalis* and *Pseudotsuga menziesii* occur rarely, only on better drained microsites. The h.t. has been partitioned into floristically distinct phases, but no definitive correlation between the phases and specific environmental conditions has been established.

Ledum glandulosum (LEGL) phase—Its presence in frost pockets and higher elevations of the h.t., as well as its reduced species richness and dominance of cold-site shrubs *L. glandulosum* and *Vaccinium scoparium*, indicate that the LEGL phase occupies the coldest sites within the ABLA/CACA h.t. The sparse coverages of *Calamagrostis canadensis* and abundance of *Xerophyllum tenax*, which is intolerant of long-persisting saturated conditions, associate these sites with the better drained portion of the h.t. Tree species' roles coincide with the h.t. description.

Vaccinium caespitosum (VACA) phase—This is a minor phase found only on the Nez Perce and southern Clearwater NF's. It occurs in frost pockets that develop in lower elevation (4,900 to 5,800 ft [1,495 to 1,770 m]) valleys or upland benches. Coarse-textured glacial outwash or stratified alluvium characterize the substrates. Adjacent, upslope positions support ABLA or ABGR series h.t.'s, usually ABGR/CLUN-XETE or ABLA/XETE. *Pinus contorta* is a persistent seral dominant; *Picea* and *A. lasiocarpa* may be slow to reinvade following disturbance. *Vaccinium caespitosum* in common coverages (≥1 percent) is diagnostic. The VACA phase often supports high coverages of *C. canadensis* and scattered *Ligusticum canbyi* and *Senecio triangularis* (fig. 25).

Ligusticum canbyi (LICA) phase—Occurrence in the low to middle subalpine zone (5,100 to 6,600 ft [1,555 to 2,010 m]), higher species richness, high constancy of wet-site herbs *Ligusticum canbyi, Trautvetteria caroliniensis, C. canadensis, Aconitum columbianum*, and *S. triangularis*, and a poorly represented shrub layer characterize the LICA phase (fig. 26). These qualities indicate that this is a more moderate phase, a possible consequence of a stronger maritime influence than received by the h.t. in general. *Picea* and *Abies lasiocarpa* codominate all successional stages; *P. contorta* shows only limited success on these sites.

Calamagrostis canadensis (CACA) phase—This is an incidental phase unrepresented by sampling and noted in reconnaissance as riparian stringers too small to sample. This is the common phase elsewhere in the Northern Rocky Mountains; in central Idaho it is characteristic of low to middle elevations of the h.t., and in Montana it is represented at high elevations. *Calamagrostis canadensis* forms a sward that obscures the forb layer. Other phase characteristics correspond to those of the h.t. level description.

Soils—All soils are developed on granitic parent materials (appendix D); only one plot contained ash. Most soils are well-drained silt loams with an average rock content of 20 percent in the surface horizon, increasing to 35 percent in subsurface horizons. Only one profile had a restrictive layer, but some test excavations indicate restrictive clay pans may be a feature distinguishing this type, particularly ABLA/CACA-VACA, from associated h.t.'s with better drainage (usually ABLA/XETE-VASC). Exposed rock and soil were not noted. Surface soils are strongly to moderately acidic (pH 5.1 to 5.6); acidity decreases slightly with increasing depth (pH 5.4 to 5.9).

Productivity/Management—Timber productivity data are meager, causing us to draw on the results of Steele and others (1981). We concur with their observations that the LICA phase is the most productive (appendix F) and LEGL is the least, and that *Picea* has the highest site index values, with *P. contorta* the most easily regenerated species. Steele and others (1981) note that partial cutting leaves the remaining trees susceptible to windthrow. As a consequence of rising water tables following overstory removal, *Carex* spp. and *C. canadensis* increase to compete with tree seedlings.

Harvesting, site preparation, and grazing of these sites should be postponed until late summer because wet soils are easily churned and compacted. Considerable forage and access to water attract livestock. These sites offer important food and cover for moose, elk, deer, bear, and Franklin's grouse (Steele and others 1981). Seral stages can support *Salix* spp. and abundant *Carex* spp.

Other Studies—ABLA/CACA has been described for Montana (three phases, Pfister and others 1977), central Idaho (four phases, Steele and others 1981), and the east slope of the Canadian Rockies (Ogilvie 1962); the type extends south and east into northwestern Wyoming (Steele

Figure 25—*Abies lasiocarpa/Calamagrostis canadensis* h.t.-*Vaccinium caespitosum* phase on a toeslope position (5,680 ft [1,730 m]) above Muleshoe Creek, Powell Ranger District. *Pinus contorta* dominates the overstory with *A. lasiocarpa* reproducing well. The low shrub layer is dominated by *V. caespitosum* and *V. scoparium*. *Xerophyllum tenax* and *C. canadensis* are the only important herbaceous components.

Figure 26—*Abies lasiocarpa/Calamagrostis canadensis* h.t.-*Ligusticum canbyi* phase on a stream terrace bordering Colt Creek (5,720 ft [1,740 m]), Powell Ranger District. At a stand age of 200 plus years *Pinus contorta* is present only as long dead snags; *Picea engelmannii* dominates the canopy and understory. *Ledum glandulosum* and four species of *Vaccinium* constitute a scattered shrub layer that is obscured by the rich herb layer dominated by *Cornus canadensis*, *Senecio triangularis*, and *Dodecatheon jeffreyi*.

and others 1983) and Utah's Uinta Range (Mauk and Henderson 1984; Youngblood and Mauk 1985). The above citations of occurrence, coupled with the knowledge that this h.t. is unreported for eastern Washington and northernmost Idaho, is circumstantial evidence connecting it with a continental climatic regime.

Abies lasiocarpa/Streptopus amplexifolius h.t. (ABLA/STAM; subalpine fir/twisted stalk)

Distribution—ABLA/STAM is a minor h.t., confined to slopes with seeps and subirrigated alluvial terraces of the subalpine zone; however, on areas with compacted till it may be locally extensive. Observed elevations in the north range from 3,300 ft (1,010 m) in some frosty bottoms, to 5,900 ft (1,800 m); and in the south, from 4,100 to 6,800 ft (1,250 to 2,075 m). A narrow ecotone generally exists between ABLA/STAM and neighboring habitat types from the Clearwater River southward, but to the north the ecotones become increasingly broader; in all cases the type is characterized by the presence of a seasonally high water table.

Vegetation—Characteristic features common to the physiognomically dissimilar phases are the dominance of *Picea engelmannii* and *Abies lasiocarpa* at all successional stages and a variable combination of the following moist- to wet-site species (in order of decreasing constancy): *Senecio triangularis, Streptopus amplexifolius, Trautvetteria caroliniensis, Veratrum viride, Ligusticum canbyi, Mitella breweri, Athyrium filix-femina,* and *Dodecatheon jeffreyi*. Low *Xerophyllum tenax* constancy and coverage further confirms the poor drainage of these sites.

Menziesia ferruginea (MEFE) phase—This phase, which occurs on the Panhandle and Clearwater NF's, on all but the highest subalpine elevations (from 4,400 ft [1,340 m]), is characterized by an open canopy structure dominated at all successional stages by *Picea* and *A. lasiocarpa*. Seral trees are limited to the sporadic occurrence of *Pinus monticola, Pinus contorta, Pseudotsuga menziesii, Larix occidentalis,* and *Abies grandis* on lower elevation sites. The undergrowth supports a variable assemblage of the above-listed forbs, and is dominated by a dense shrub layer of *Menziesia ferruginea* and *Vaccinium globulare* (fig. 27). On the Kaniksu NF, in areas with deep snowpacks, *Rhododendron albiflorum* adds to the shrub-dominated aspect in at least half the stands. Adjacent drier sites frequently support ABLA/CLUN-MEFE or ABLA/MEFE.

Figure 27—*Abies lasiocarpa/Streptopus amplexifolius* h.t.-*Menziesia ferruginea* phase on a slightly inclined bench in the Canuck Pass-American Mountain, ID, vicinity (5,650 ft [1,720 m]). This view emphasizes the typically open canopy dominated by *Picea engelmannii* and *A. lasiocarpa*. The undergrowth is dominated by a very dense cover of *M. ferruginea* and *Rhododendron albiflorum* beneath which occurs a diverse assemblage of wet-site species.

Ligusticum canbyi (LICA) phase—This phase is common on the Nez Perce and Clearwater NF's, with declining representation to the north. The sampled elevation range was 4,250 to 6,750 ft (1,295 to 2,060 m), but outliers were noted in cold valleys as low as 3,300 ft (1,010 m). Lacking the shrub coverage typical of STAM-MEFE, these sites support a more closed canopy of *A. lasiocarpa* and *Picea* and a forb-dominated undergrowth (fig. 28). Seral tree species apparently are even more limited here than in the MEFE phase; *Pseudotsuga* and *P. contorta* occupy the better drained microsites.

Soils—Parent materials are dominated by alluvium, especially in the LICA phase, and include granitics, sandstone, quartzite, and mica schist (appendix D). Restrictive layers, primarily clay pans and compacted glacial till, are found on virtually all the LICA and half of the MEFE sites. Most of the MEFE sites have a deep (13 inches [33 cm] average) ash cap, whereas ash influences were limited in the LICA phase. Though gravel content varies widely, low content (<5 percent) prevails in both the surface and lower horizons on benches, stream terraces, and toe-slope positions; across both phases and all soil depths gravel content averages only 16 percent. The range in surface and subsurface soil textures is narrow, loam to silty clay loam. Effective rooting depths are relatively shallow (average of 14 inches [36 cm]), reflecting the presence of high water tables and saturated soils. Soil reaction (pH) for surface and subsurface horizons is strongly to moderately acidic.

Productivity/Management—Timber potential varies from moderate, where cold-air drainage is impeded and soils are saturated throughout the year, to very high on sites with better drainage; on these better drained sites *Picea* has the highest site index values (appendix F). Caution should be exercised in timber management; clearcutting will negate the high probability of windthrow associated with partial cutting, but the resulting rise in water tables may produce herb-dominated meadows that reforest very slowly. Light selection cutting may avoid these pitfalls, but heavy equipment use should be delayed until the late summer. Roads, trails, or other site development should be avoided. Cole (1983) showed trails crossing this h.t. to be in much poorer condition than those trail portions located in h.t.'s with higher drainage rates.

The abundant forage found in the LICA phase and adjacent watercourses attracts livestock; soils on these sites are easily churned, destroying undergrowth and tree seedlings. Elk use of lower elevations within the MEFE phase is moderate to high for cover and forage. Mountain caribou use old-growth stands as part of their winter range because the lower branches are festooned with lichens, an important part of their nutrition (Edwards and others 1960; Edwards and Ritcey 1960).

Figure 28—*Abies lasiocarpa/Streptopus amplexifolius* h.t.-*Ligusticum canbyi* phase on a terrace adjacent to Beaver Creek (3,780 ft [1,150 m]) on the St. Joe NF. The frosty bottomland position accounts for the dominance of uneven-aged *Picea engelmannii* and *A. lasiocarpa* and exclusion of *Thuja* from a site surrounded by the THPL series. The undergrowth, dominated by *Athyrium filix-femina*, *Gymnocarpium dryopteris*, *Trautvetteria caroliniensis*, and *L. canbyi*, is typical of the THPL/ATFI h.t.

Other Studies—The forb-dominated phases of this type are documented to the south and east of the study area: Uinta Mountains of Utah (Mauk and Henderson 1984; Youngblood and Mauk 1985), Teton and Absaroka Mountains of Wyoming (Steele and others 1983), central Idaho (Steele and others 1981), and in Montana (Pfister and others 1977) as ABLA/CACA-GATR and portions of ABLA/GATR. In northeastern Washington Lillybridge and Williams (1984) have sampled numerous stands (scattered among three associations, ABLA/COCA [*Cornus canadensis*], ABLA/LIBO [*Linnaea borealis*], and ABLA/RHAL [*Rhododendron albiflorum*]) that would key to and match the description for either phase of our ABLA/STAM h.t. In southern Alberta, Ogilvie (1962) has documented an h.t., ABLA-PIEN/*Tiarella trifoliata*-MEFE, closely corresponding to our MEFE phase.

Abies lasiocarpa/Clintonia uniflora h.t. (ABLA/CLUN; subalpine fir/queencup beadlily)

Distribution—ABLA/CLUN is a major subalpine h.t., increasing in extent from the Kaniksu to the Nez Perce NF; its continuity is broken on the southern Coeur d'Alene, St. Joe, and northern Clearwater NF's, replaced by the TSME/CLUN h.t. on similar sites. It ranges from 4,600 to 5,600 ft (1,400 to 1,710 m) in the north and from 5,000 to 5,900 ft (1,525 to 1,800 m) in the south. The XETE phase occupies higher elevations and warmer slopes, while the MEFE phase occurs at lower elevations on north-facing slopes. The warm extreme of ABLA/CLUN grades to TSHE/CLUN in the north, to THPL/CLUN on the Clearwater and northern Nez Perce NF's, and to ABGR/CLUN on the southern Nez Perce NF. Its cold-dry extreme borders on ABLA/MEFE and ABLA/XETE throughout the study area.

Vegetation—*Pseudotsuga menziesii*, *Picea engelmannii*, *Pinus contorta*, and *Larix occidentalis* are important seral species; their success is related to phase and locality. In late seral stands *Picea* is a major component, with *Abies grandis* commonly persisting as a minor climax component. Copious advance regeneration of *Abies lasiocarpa* is common, even in young stands.

The undergrowth is a variable mixture of forbs and shrubs, richer in species number and generally higher in coverages than other ABLA h.t.'s. The presence of *Clintonia uniflora* is indicative of this h.t.; other mesic forbs of high constancy are *Tiarella trifoliata*, *Coptis occidentalis*, *Trillium ovatum*, *Goodyera oblongifolia*, and *Bromus vulgaris*. *Thalictrum occidentale* and *Xerophyllum tenax* also have high constancy. Of the shrub component, *Vaccinium globulare*, *Menziesia ferruginea*, and *Lonicera utahensis* have high constancy, but only the first two attain abundant coverages.

Menziesia ferruginea (MEFE) phase—This phase is characteristic of moist, cold, northerly slopes and frost pockets, and grades to ABLA/MEFE on still colder and possibly drier (better drained) sites. *Abies lasiocarpa* and *Picea* codominate late seral stands and are also important early in the sere, followed in order of importance by *P. contorta* and *Pseudotsuga*. The low importance of *P. contorta* reflects the old age (average = 180 years) of sampled stands; reconnaissance of younger stands (<100 years) indicated *P. contorta* to be the major seral tree. For reasons not evident, *L. occidentalis* and *Pinus monticola* are insignificant compared to their representation in the same phase in Montana. The lush undergrowth is dominated by *M. ferruginea*, *V. globulare*, and *X. tenax* (fig. 29). *Alnus sinuata* and *Sorbus scopulina* may increase markedly following disturbance and delay or prevent full stocking.

Xerophyllum tenax (XETE) phase—This phase, characterized by the dominance of *Xerophyllum* and *V. globulare*, is indicative of the warm, relatively dry environments within the type. It is found predominantly on south- and west-facing slopes. At lower elevations it grades to ABGR/CLUN-XETE or THPL/CLUN, and above or on drier sites to ABLA/XETE.

Seral tree species, more abundant in this phase than ABLA/CLUN-MEFE, are, in order of decreasing importance, *Pseudotsuga*, *L. occidentalis*, *P. contorta*, and *P. monticola*. *Picea* does not attain the late seral dominance here that it does in the other phases. The relatively high constancy and coverage of *A. grandis* reflect the relatively warm site conditions of this phase.

Clintonia uniflora (CLUN) phase—This is a minor phase, especially compared to its prominence in Montana. Its small areal extent in northern Idaho is explained by the fact that moderate environments, of which it is typical, are occupied by more competitive (shade-tolerant) tree species. The CLUN phase is characterized by the absence or poor representation of *Menziesia* and *Xerophyllum* and a corresponding increase in forb coverages in all but closed-canopy seral stages.

Soils—Parent materials are dominated by granitics, quartzites, and mica schists (appendix D). Surface soils are generally dominated by an ash cap (andic diagnostic horizon) averaging over 12 inches (30 cm) in depth (ranging from 3 to 24 inches [8 to 60 cm] thick). Surface horizon textures are primarily loams to silt loams; subsurface textures are highly variable. Rock content averages 17 percent in the surface horizons and does not increase appreciably with depth. The MEFE phase has slightly deeper rooting depths than the XETE phase, 23 inches (58 cm) (14 to 43 inches [35 to 110 cm]) versus 18 inches (45 cm) (11 to 21 inches [28 to 53 cm]). Restrictive layers are found only in the XETE phase. Surface soil pH ranges from strongly acidic to neutral; acidity decreases slightly with increasing depth.

Productivity/Management—Timber potentials are generally high for all seral species, ABLA/CLUN being the most productive sites in terms of site index and basal area of all subalpine h.t.'s (appendix F). Based on limited site index data, the three phases appear equally productive, though natural understocking commonly occurs on the MEFE phase. *Pseudotsuga* and *Larix* readily establish here and exhibit high growth rates. Vast acreages, however, support an overstory of only *Pinus contorta* (with *A. lasiocarpa* and *Picea* as understory) because of their fire history coupled with poor *Pseudotsuga* and *Larix* cone crops. *Picea* is the highest site index species on all phases, but regeneration may be considerably delayed and in lesser amounts than *P. contorta* or *Pseudotsuga*. The diversity of seral species and high productivity of this h.t.

Figure 29—*Abies lasiocarpa/Clintonia uniflora* h.t.-*Menziesia ferruginea* phase on a steep northeast-facing slope (5,450 ft [1,660 m]) in the Horse Creek headwaters vicinity, Nez Perce NF. The canopy of *A. lasiocarpa*, *A. grandis*, and *Picea engelmannii* is typically open, however the shrub cover is unusually sparse. The undergrowth is very rich and dominated by *Arnica latifolia*, *Syntheris platycarpa*, *C. uniflora*, and *Coptis occidentalis*.

permits the greatest range of silvicultural options for subalpine sites. Partial cutting will accelerate *A. lasiocarpa*, and to a lesser degree *Picea*, dominance.

Fiedler's (1980) studies on the ABLA/CLUN h.t. in western Montana have established that the probability of immediate natural stocking following clearcutting is high, 70 to 80 percent, and does not improve significantly over the following 10 years. Probability of stocking is higher with site scarification than with burning for approximately 12 years following treatment. Undergrowth coverages above 10 to 15 percent are correlated with significantly reduced stocking probability; in 12 years at 100 percent undergrowth coverage (no site preparation), only 60 percent stocking is achieved. The MEFE phase usually requires more intensive site preparation because of possible shrubfield development.

Seral shrubs can produce considerable summer browse for elk and deer; the lower elevation sites within the MEFE phase constitute a portion of moose winter range on the Nez Perce NF. Along the Canadian border ABLA/CLUN is one of the major h.t.'s, serving as critical winter range for woodland caribou (Edwards and Ritcey 1960; Edwards and others 1960). The lush forage produced in openings and early seral stages attracts livestock.

Watershed values are high because of heavy snowpack and high precipitation, typical across most of the subalpine zone (appendix E).

Other Studies—ABLA/CLUN represents the major portion of what Daubenmire and Daubenmire (1968) described as ABLA/*Pachistima myrsinites* and includes the moist portion of their ABLA/MEFE and ABLA/XETE h.t.'s. The type is very extensive and environmentally diverse in northwestern Montana beyond the range of *Tsuga* and *Thuja* (Pfister and others 1977) and extends north into Alberta (as ABLA-PICEA/TITR-MEFE) (Ogilvie 1962) and British Columbia (Utzig and others 1983; Wali and Krajina 1973), south to central Idaho (Steele and others 1981), and west to northeastern Washington (as portions of the ABLA/COCA, ABLA/LIBO, ABLA/VACCI [*Vaccinium* spp.] and ABLA/RHAL associations) and east slope of the Cascades and Okanogan Highlands (Lillybridge and Williams 1984; Williams and Lillybridge 1983). The majority of stands sampled by Lillybridge and Williams (1984) appear to floristically resemble our CLUN phase of ABLA/CLUN, which occurs infrequently in northern Idaho.

Abies lasiocarpa/Menziesia ferruginea h.t. (ABLA/MEFE; subalpine fir/menziesia)

Distribution—ABLA/MEFE is a common h.t. on the Nez Perce and Clearwater NF's, its areal extent dwindling to the north, but nowhere in northern Idaho does it attain the abundance displayed in western Montana (Pfister and others 1977). On the Kaniksu NF it ranges from 4,900 to 6,500 ft (1,495 to 1,980 m) but can occur as much as 1,000 ft (305 m) lower in frost pockets. It ranges from 5,100 to 7,300 ft (1,555 to 2,225 m) on the Nez Perce NF. At lower elevations ABLA/MEFE is confined to predominantly steep, sheltered, northerly aspects. With increasing elevation it may move onto sheltered westerly or easterly slopes or even ridgetops. It gives way below on more moist, moderate sites to ABLA/CLUN-MEFE, with which it is easily confused in the field, and grades to ABLA/XETE on warmer exposures.

Vegetation—Common to all phases is the clear dominance of *Abies lasiocarpa*, followed in importance by *Picea engelmannii*, which persists as massive old-growth trees. Seral *Pinus contorta* is short-lived, dying out almost completely in 160 years. Though *P. contorta* is capable of establishing in nearly pure, even-aged stands, it is poorly represented over considerable acreages where long (>200 years) fire-free intervals have prevented maintenance of a seed source. Other seral tree species are distributed according to phase.

The characteristic tall shrub layer is dominated by a dense growth of *Menziesia ferruginea* (6 to 8 ft [1.8 to 2.4 m], extremes 3 to 10 ft [0.9 to 3.0 m]), and commonly joined by *Rhododendron albiflorum* on higher elevations of the Kaniksu and Coeur d'Alene NF's. On the northernmost portions of the Kaniksu NF, reconnaissance of the highest elevations revealed stands with the tall shrub layer composed of only *R. albiflorum*; these sites occur above the limits of *M. ferruginea* and *Vaccinium globulare* and presumably indicate cold-wet conditions that are described in the Canadian (Utzig and others 1983) and coastal literature (Hemstrom and others 1982). *Vaccinium globulare* is abundant in all phases, but its size parallels the severity of the site and even approaches dwarf shrub status. The herb layer, depauperate by comparison to that of the ABLA/CLUN-MEFE h.t., is strongly dominated by *Xerophyllum tenax*; *Goodyera oblongifolia* and *Viola orbiculata*, in trace amounts, are the only forbs approaching 50 percent constancy.

Luzula hitchcockii (LUHI) phase—The LUHI phase is found at the highest elevations of the type (up to 6,500 ft [1,980 m] in the north and 7,300 ft [2,225 m] in the south) where it is bordered by ABLA/XETE-LUHI on warmer aspects and ABLA/LUHI on exposed areas. Typically these sites are steep northerly aspects, immediately downslope from ridgelines. This phase is indicative of cold, relatively harsh sites where the snowpack may persist long into the growing season. Supporting this interpretation is the high constancy of seral *Pinus albicaulis*, low species diversity of the undergrowth, and high coverages of the diagnostic species *L. hitchcockii*. Where tree canopy coverages are low, *Luzula hitchcockii* and *Vaccinium scoparium* may form a dense undergrowth; on some sites *L. hitchcockii* occurs only in the lee of mature tree atolls (fig. 30).

Vaccinium scoparium (VASC) phase—On the gradient of increasing site severity, from ABLA/MEFE-COOC to MEFE-LUHI, the VASC phase typifies intermediate sites. This phase is most common in the southeastern part of northern Idaho and generally is found above 6,000 ft (1,830 m) and near ridgelines. Though these tend to be microclimatically severe sites, they experience earlier snowpack melt-off than the LUHI phase. *Pinus contorta* is the most important seral tree species, followed by *Picea* and *P. albicaulis*. *Abies lasiocarpa* can rapidly reforest these sites, sometimes to the near exclusion of seral species. Undergrowth follows the type description with the addition of a low shrub layer of *V. scoparium*.

Coptis occidentalis (COOC) phase—This phase, indicated by common coverages of *Coptis*, represents the most moderate sites within the type, those transitional to ABLA/CLUN-MEFE and ABGR/CLUN-MEFE. Species diversity and forb coverage and constancy, especially for *Pyrola asarifolia*, *Trillium ovatum*, and *G. oblongifolia*, are the highest within the type. The moderate nature of these sites is reflected in the increased seral importance of *Pseudotsuga menziesii* and *Larix occidentalis*, which still considerably trail *Picea* in abundance and timber potentials.

Xerophyllum tenax (XETE) phase—This is the common phase at lower elevations of the subalpine zone (to 6,900 ft [2,100 m] on the Nez Perce NF, and 6,000 ft [1,830 m] on the Kaniksu NF). *Larix occidentalis*, *Pseudotsuga*, and *Pinus monticola* are minor seral components; other features follow the type description.

Soils—Within ABLA/MEFE, four phases are recognized; compared below are two phases for which we possess limited soils information, the most moderate phase, COOC, and the most environmentally stressed phase, LUHI. Parent materials are exclusively granitics and mica schists. Ash layers are present on most sites; depths of those on the COOC phase averaged 15 inches (38 cm) and on the LUHI phase only 7 inches (18 cm). No restrictive layers are found in either phase. Surface soil textures are consistently silt loams in the COOC phase and more variable in the LUHI phase. The two phases show notable differences in gravel content. COOC surface soils are nearly devoid of gravel, and content increased an average of only 5 percent to the subsoil depths. In contrast, LUHI soils are gravelly in the surface portion (30 percent average) and content increases markedly with depth, to an average of 60 percent. LUHI also exhibits higher soil acidity than COOC in both the surface (pH 4.7 versus 5.8) and subsurface (pH 5.3 versus 5.8) horizons.

Productivity/Management—Based on limited data it appears there is a distinction between phases for timber potentials (appendix F), the COOC phase having the highest site index values. *Picea* has the highest site index and is the most important species (basal area) on all phases, although absolute values of site index range upward to high only on the XETE and COOC phases; on the VASC and LUHI phases the 50-year site index for *Picea* does not exceed 58 to 60. *Pinus contorta* exhibits moderate site index values on the XETE and VASC phases and reduced potential on the more severe LUHI phase.

Figure 30—*Abies lasiocarpa/Menziesia ferruginea* h.t.-*Luzula hitchcockii* phase on a bench (6,180 ft [1,885 m]) east of Saddle Lake, Kaniksu NF. The tree canopy is comprised of nearly pure, uneven-aged *A. lasiocarpa*. The dominant shrub, *Rhododendron albiflorum*, is relatively short, barely 3 ft (1 m) on this harsh site. *Luzula hitchcockii* and *Arnica latifolia* are the only undergrowth species present in more than trace amounts.

Roe and DeJarnette (1965) state that the best *Picea* growth is attained on clearcuts, but that ample regeneration is achieved only in partially shaded openings of scarified sites. Fiedler (1982) has shown for ABLA/MEFE (no phase designated) in western Montana: (1) High relative importance of *Picea* (followed closely by *A. lasiocarpa* and distantly by *P. contorta*) extends to the earliest seral stages following clearcutting. (2) Total undergrowth coverage exceeding 50 percent (contributed by increased *Menziesia*, *Vaccinium* spp., and *Alnus sinuata*) is correlated with retardation of natural regeneration by up to 60 percent of possible stocking for at least 12 years. (3) Considerably higher (by 10 to 30 percent) probabilities of natural stocking follow scarification, as opposed to burning (however, slopes too steep for scarification dictate burning during the few times when fuels are dry). (4) ABLA/MEFE displays a high probability for natural stocking, considering 82 percent stocking results 7 to 10 years following cutting, regardless of treatment. (5) The success rate of planted regeneration (the most frequently employed strategy) is relatively high (75 percent), and 35 percent of these planting attempts achieved a super-abundant stocking because natural regeneration was adequate. Silvicultural recommendations of Boyd and Deitschman (1969) may also apply here.

The harsher environments and lower productivity of the VASC and LUHI phases suggest silvicultural prescriptions should consider minimal site disturbance. The consistently deep snowpack will tend to increase in clearcuts, in some cases promoting a *Luzula* sward and/or *Menziesia*- and *Alnus*-dominated shrubfields that can appreciably retard reforestation. Partial cuttings will expose these high-elevation, fragile sites, risking heavy blowdown in *Picea* and promoting dominance by *A. lasiocarpa*.

Livestock grazing has little potential, but big game, especially elk and moose, use these areas in summer for cover and browse. Along the northern border of the Kaniksu NF, mature stands of ABLA/MEFE serve as critical winter range for mountain caribou, their principal forage being epidendric lichens encrusting older trees (Edwards and others 1960). Watershed values are high.

Other Studies—Daubenmire and Daubenmire (1968) first described ABLA/MEFE in northern Idaho and did not partition the variability into phases, as was done in Montana by Pfister and others (1977), and in central Idaho by Steele and others (1981). Virtually the same environments as we describe (LUHI, VASC, XETE phases only) are described for northeastern Washington as the modal portions of the ABLA/RHAL (*Rhododendron albiflorum*) association of Lillybridge and Williams (1984). The most distant described regional extensions of this type appear to be southwestern Alberta (Ogilvie 1962), southeastern British Columbia (Utzig and others 1983), and northwestern Wyoming (Steele and others 1983).

Abies lasiocarpa/Vaccinium caespitosum h.t. (ABLA/VACA; subalpine fir/dwarf huckleberry)

Distribution/Vegetation—ABLA/VACA is an incidental h.t. described from reconnaissance data on the southern and western Nez Perce NF. It is consistently found on gently rolling to flat terrain at lower to midelevations (5,200 to 6,700 ft [1,585 to 2,040 m]), usually valleys where cold air may be impounded. These sites typically are mantled with coarse-textured glacial drift, predominantly outwash. Daubenmire (1980) documents the regional importance of cold-air drainage and topographic situations producing frost pockets and their characteristic vegetation.

Sites are dominated by persistent, but seral, *Pinus contorta. Picea engelmannii* and *Abies lasiocarpa* are slow to recolonize and characteristically have slow growth and poor form. Other coniferous species are usually lacking. *Vaccinium caespitosum* is diagnostic for the type, occurring as a discontinuous layer with *Calamagrostis rubescens* and *Carex geyeri* and joined by *Vaccinium scoparium* on more severe sites. The few forbs present are obscured by the subshrub and graminoid layer (fig. 31).

Productivity/Management—Based on data from contiguous areas, timber productivity ranges from low to moderate, with *P. contorta* the only species well suited for management (Pfister and others 1977; Steele and others 1981). These populations have predominantly nonserotinous cones, accounting for the high rate of seedling establishment in the absence of disturbance. Gentle terrain and stable soils should favor intensive silviculture. However, the frost pocket microclimate argues otherwise; data assessing response to treatment are wanting.

Livestock find moderate forage, provided by *C. rubescens* and *C. geyeri*, and favorable terrain. Proximity to moist meadows suits these sites for summer and fall elk and deer use as cover.

Other Studies—This type is best represented beyond the influence of the inland maritime climatic regime, ranging from Alberta (Ogilvie 1962, as portions of the *Picea-Abies/Calamagrostis* h.t.) through eastern Montana (Pfister and others 1977) to central Idaho (Steele and others 1981) and northern Utah (Henderson and others 1976). For northeastern Washington Lillybridge and Williams (1984) describe an ABLA/VACCI association for which *V. caespitosum* is ostensibly the diagnostic species. Habitats described for their association are very similar to those of our ABLA/VACA h.t., but floristic composition of their stands reveals a wider range of environments.

Figure 31—*Abies lasiocarpa/Vaccinium caespitosum* h.t. on a gentle toeslope associated with frost-pocket conditions (5,320 ft [1,620 m]) on Red River Ranger District, Nez Perce NF. This midseral stand is dominated by *Pinus contorta* in the overstory, with *V. caespitosum* and *V. scoparium* forming a low shrub layer; *Xerophyllum* is the only forb of importance.

Abies lasiocarpa/Xerophyllum tenax h.t. (ABLA/XETE; subalpine fir/beargrass)

Distribution—ABLA/XETE is an abundant h.t. on the Nez Perce and southern Clearwater NF's, decreasing in importance to the north. It is strongly associated with steep, warm exposures with well-drained soils but also occurs on benchlands. Observed elevational range was 5,100 to 6,200 ft (1,550 to 1,890 m) in the north and 5,300 to 7,600 ft (1,615 to 2,320 m) on the Nez Perce NF. It usually grades to ABLA/MEFE phases on colder sites and to ABLA/CLUN-XETE on moderated environments.

Vegetation—*Abies lasiocarpa* is usually well represented even in early seral stands and increases in importance to dominate these sites as in no other subalpine zone h.t.; conversely, *Picea engelmannii* occurs only sporadically. Seral tree occurrence and growth vary by phase.

Generally abundant *X. tenax* and *Vaccinium globulare* (on all but the coldest sites) are the only undergrowth species with high constancy in all phases.

Luzula hitchcockii (LUHI) phase—The LUHI phase delineates the highest elevations (5,700 to 7,600 ft [1,740 to 2,320 m]) or areas where snowpacks remain well into the growing season. The severity of these sites is reflected by: (1) the much lower coverage constancy and diminutive form (12 to 20 inches [30 to 50 cm]) of *V. globulare*, (2) the depauperate forb layer, (3) the occurrence of *Luzula hitchcockii* and *Phyllodoce empetriformis* and high coverages of *Vaccinium scoparium*, (4) the absence of *Pseudotsuga menziesii*, and (5) the waning of *Pinus contorta*'s seral importance and increase in that of *Pinus albicaulis*.

Vaccinium scoparium (VASC) phase—The VASC phase occurs predominantly on the Clearwater and Nez Perce NF's. Though ranging from 5,200 to 6,900 ft (1,585 to 2,105 m), it defines predominantly upper elevation sites (>5,900 ft [1,800 m]), frost pocket conditions, or relatively severe, windswept, near-ridgeline positions. The undergrowth may be quite dense with a layer of *V. scoparium* surrounding clumps of *Xerophyllum* over which *V. globulare* is superimposed (fig. 32). Excepting *X. tenax*, the forb layer is sparse; only *Viola orbiculata* is even moderately constant. *Pinus contorta* is the major seral species followed distantly by, in order of decreasing importance, *Picea*, *Pseudotsuga*, and *P. albicaulis*.

Coptis occidentalis (COOC) phase—Recognized by the common coverage of *Coptis*, the COOC phase is indicative of the most moderate sites within the type, those transitional to ABLA/CLUN-XETE, ABGR/CLUN-XETE, and ABGR/XETE. It was found only on the Clearwater and Nez Perce NF's. It commonly occurs between 5,200 and 5,900 ft (1,585 and 1,800 m) (extremes to 6,400 ft [1,950 m]) and predominantly on east- and west-facing aspects. The moderated conditions of this phase are reflected in relatively high constancy and coverage for *Abies grandis*, *Picea*, and *Pseudotsuga*; *P. contorta* is still the major seral tree. Higher constancy for *Viola orbiculata*, *Anemone piperi*, and *Goodyera oblongifolia*, and generally greater undergrowth diversity, distinguish this phase (fig. 33).

Vaccinium globulare (VAGL) phase—This phase occurs at lower elevations of the h.t. (<6,400 ft [1,950 m]) and represents modal conditions within the type. It supports a variety of seral tree species, of which only *P. contorta*, *Pseudotsuga*, and *Larix occidentalis* are important. *Pinus monticola* may be locally significant from the Clark Fork River drainage northward. *Calamagrostis rubescens* and *Carex geyeri* have high constancy and are locally abundant in this phase. The VAGL phase grades to ABLA/MEFE-XETE on northerly, sheltered positions and ABLA/XETE-VASC on colder, drier sites.

Soils—Parent materials included, in decreasing frequency of occurrence, granitics, gneiss, mica schist, and rhyolite (appendix D). Only one restrictive layer was found in 30 profiles. The ash cap influence is strong (averaging 14 inches [35 cm] in depth) in all phases but LUHI, where it is conspicuously reduced. Surface horizons in COOC and VAGL phases are exclusively silt loams and loams, whereas for VASC and LUHI the textural range is much greater; soil textures increase in coarseness with increasing depth. Surface soil gravel content averages about 15 percent for COOC, XETE, and VASC with LUHI averaging approximately double this value; subsurface soil gravel content increases with depth and averages about twice that of the surface soil for all phases. Rooting depth averages 16, 20, 21, and 13 inches (41, 50, 53, and 33 cm) for COOC, VAGL, VASC, and LUHI phases, respectively. In accordance with expectations of increasing precipitation and hence increased leaching, the surface soil pH decreases along the gradient COOC (5.9), VAGL (5.8), VASC (5.6), LUHI (5.2); subsoil pH values are slightly higher but approximate the surface soil gradient.

Productivity/Management—Site index data are sketchy but indicate a steady decline by phase from moderate to high in VAGL and COOC, low to moderate in VASC, and low in LUHI (appendix F). The VAGL and COOC phases offer the most opportunity for mixed species management; in order of decreasing potential they are *P. contorta*, *Pseudotsuga*, *Picea*, and *L. occidentalis*.

Fiedler (1980) has shown that following clearcutting on the VAGL phase in northwestern Montana (1) undergrowth has a dramatic, inverse correlation with tree stocking at tree coverages greater than 25 percent; (2) scarification is preferable to burning in achieving regeneration the first 9 to 10 years following cutting—the "no treatment" alternative following cutting is least successful; and (3) *A. lasiocarpa* seedlings constituted 40 percent of natural regeneration in 12 years, followed distantly by *Pseudotsuga* (18 percent) and, in order of decreasing amounts, *P. contorta*, *Picea*, and *L. occidentalis*. *Abies lasiocarpa*, though relatively prolific in regeneration, has slow initial growth, with seedlings concentrated in the lower crown class. Planting of these sites in areas with an abundant seed source seems unwarranted. Some of these results can be extrapolated to the VASC phase.

Timber management for VASC and LUHI phases should concentrate on *P. contorta* and *Picea*. These are severe sites; however, the creation of forest openings through patch clearcutting can cause increased snow deposition and retarded reforestation. Partial cutting leaves *Picea* susceptible to windthrow, while advance regeneration of *Abies lasiocarpa* may be released to dominate the stand.

Livestock grazing potential is low in all phases. Evidence of light to moderate use by elk and deer is present

Figure 32—*Abies lasiocarpa/Xerophyllum tenax* h.t.-*Vaccinium scoparium* phase on a gently sloping ridge shoulder (6,520 ft [1,990 m]) east of Dixie Guard Station, Nez Perce NF. Even-aged *Pinus contorta* dominates the overstory, with *A. lasiocarpa* and *Picea* scattered in the understory. A low mat (8 inches [20 cm]) of *V. scoparium* is interspersed with clumps of *X. tenax*.

Figure 33—*Abies lasiocarpa/Xerophyllum tenax* h.t.-*Coptis occidentalis* phase on a gentle east-facing slope (6,000 ft [1,830 m]) north of Dixie Summit, Nez Perce NF. *Pseudotsuga* dominates this multiple-aged stand (180 years old) and is currently reproducing in greater numbers than *A. lasiocarpa*. Undergrowth is dominated by *Vaccinium globulare*, *Spiraea betulifolia*, and *X. tenax*.

in the VAGL phase in early and midsummer, with herds moving through all phases by late summer-early fall. *Xerophyllum* flowering heads were consistently cropped in some areas and individual *V. globulare* plants were hedged to less than 1 ft (30 cm) in height. Mainly bears and grouse feed on the huckleberry crop.

Watershed management opportunities are greatest in the VASC and LUHI phases; in general, moderate to high precipitation occurs here, with high rates of evapotranspiration and runoff characteristic of these generally southerly slopes.

Other Studies—Daubenmire and Daubenmire (1968) first described the ABLA/XETE h.t. for northern Idaho, combining all phases recognized here. Lillybridge and Williams (1984) recognize an ABLA/XETE association which is restricted to east of the Pend Oreille River in Washington. For Montana, Pfister and others (1977) recognize VASC and VAGL phases similar to ours, but they assign stands containing *L. hitchcockii* to ABLA/LUHI. We follow Steele and others' (1981) classification for central Idaho; they discount the indicator value of *L. hitchcockii* because it extends to relatively lower elevations of the subalpine zone than in Montana. Ogilvie (1962) for southeastern Alberta and Cooper (1975) for northwestern Wyoming describe known outliers of the type.

Abies lasiocarpa/Vaccinium scoparium h.t. (ABLA/VASC; subalpine fir/grouse whortleberry)

Distribution—As Daubenmire and Daubenmire (1968) noted, ABLA/VASC is poorly represented where the inland maritime climatic influence is strongest. Thus it was noted in reconnaissance as an incidental type found only at the periphery of the study area, the Seven Devils Mountains, and southern Nez Perce NF. In eastern Washington Lillybridge and Williams (1984) identified ABLA/VASC as a minor type and in northwestern Montana the h.t. was not found (Pfister and others 1977). It was not observed below 6,200 ft (1,890 m) and showed no aspect preference. Of the three phases noted for central Idaho and Montana, only the VASC phase (characteristic of the most severe environments) was identified in northern Idaho.

Vegetation—*Picea engelmannii* and *Abies lasiocarpa* are slow to reestablish on these harsh sites that are dominated in seral stages by mostly nonserotinous *Pinus contorta*. *Pinus contorta* readily reproduces, even before the breakup of the densely stocked stands. *Pinus albicaulis* may be a significant seral component at the highest elevations. The undergrowth is dominated by a low layer of *Vaccinium scoparium*; the herbaceous layer is rather depauperate, with only *Arnica* spp., *Lupinus* spp., *Carex geyeri*, and *Carex rossii* normally present.

Productivity/Management—See Steele and others (1981) and Pfister and others (1977) for detailed management considerations. Reconnaissance observations suggest *P. contorta* is the only suitable timber species, regenerating easily in unshaded clearings, but having poor height growth.

Other Studies—ABLA/VASC is one of the most wide-ranging, areally extensive subalpine h.t.'s in the Interior West, having varying degrees of compositional differences, from British Columbia and Alberta (Illingsworth and Arlidge 1960; Ogilvie 1962) south to Arizona and New Mexico (Moir and Ludwig 1979).

Abies lasiocarpa/Luzula hitchcockii h.t. (ABLA/LUHI; subalpine fir/smooth woodrush)

Distribution—ABLA/LUHI is a minor h.t. in northern Idaho, confined to the highest and harshest sites where snowpacks remain late into summer. It was found as low as 6,000 ft (1,830 m) on the Kaniksu NF but ranges to 8,000 ft (2,440 m) on the Nez Perce NF.

Vegetation—Trees tend to occur in clusters. The multiple-stemmed condition of *Pinus albicaulis*, the major seral species, may result from germination of unharvested avian (Lanner 1980) or rodent seed caches. *Picea* and *Abies lasiocarpa* are well represented to abundant on all but the youngest seral stages. ABLA/LUHI sites occur above the limits of *Pseudotsuga*, *Larix occidentalis*, and *Pinus monticola* and are marginal for *Pinus contorta* establishment.

The undergrowth is species-poor and coverages vary considerably. *Luzula hitchcockii* sometimes occurs as a dense sward with *Vaccinium scoparium* and *Phyllodoce empetriformis* superimposed. *Valeriana sitchensis* and *Arnica latifolia* are characteristic of the more moist sites (fig. 34).

Soils—Because all samples with soils information were collected on the eastern portions of the Nez Perce NF where the Idaho batholith predominates, granitics were the only parent materials represented (appendix D). Very limited data show soil textures, rock content, and rooting depth to vary widely; no restrictive layers were found. Generally there is little exposed soil, but exposed rock may be considerable. Surface horizons are very acidic (pH 4.2 to 4.8), with values increasing with depth (lower profile pH 5.1 to 5.3).

Productivity/Management—Timber potentials are low (appendix F). Seral tree regeneration may be difficult to achieve due to heavy snowpack, competition from a sward of *Luzula*, and advance regeneration of *Abies lasiocarpa* (frequently vegetatively layering).

These are fragile sites due to their harsh environments. Apparently only the Seven Devils area has been subjected to the degrading forces of intensive sheep trailing cited by Steele and others (1981) as extensive in central Idaho. Key management concerns include watershed protection and maintenance of "high country" esthetics for recreation.

ABLA/LUHI provides summer and fall cover and forage for elk, deer, mountain goats, bighorn sheep, and bears.

Other Studies—In central Idaho, where there is much more high-elevation country capable of supporting ABLA/LUHI, Steele and others (1981) have recognized LUHI and VASC phases; Pfister and others (1977) in Montana have defined a broader LUHI h.t. by emphasizing the mere presence of *Luzula hitchcockii*. We often noted *L. hitchcockii* occurring far downslope, distant from an upper subalpine environment, and thus did not accord the same indicator significance as in Montana environments.

Figure 34—*Abies lasiocarpa/Luzula hitchcockii* h.t. on a gentle west-facing slope near Heaven's Gate Lookout, ID (8,150 ft [2,485 m]), Nez Perce NF. Except where erosion pockets occur, *L. hitchcockii* approaches sward-like conditions under an open canopy of *A. lasiocarpa* and *Pinus albicaulis*. Minor amounts of *Lupinus*, *Penstemon*, *Phlox*, and *Polemonium* species also occur.

Larix lyallii-Abies lasiocarpa h.t.'s (LALY-ABLA; alpine larch-subalpine fir)

Distribution/Vegetation—Occurring at the outer fringe of the maritime mountain climates on cold exposures with limited soil development, LALY-ABLA h.t.'s have been classified only for Montana timberlines (Pfister and others 1977) west of the Continental Divide. According to the distribution map of Arno and Habeck (1972), this complex occurs along the highest peaks of the Bitterroot Mountains (Idaho-Montana border) and northward as isolated occurrences at Roman Nose and Northwest Peak on the Kaniksu NF, making it a very incidental type. Although we have not sampled this type, we have used the plural designation to indicate the possibility of diverse types. See Pfister and others (1977) and Arno and Habeck (1972) for community descriptions and management implications.

Generally the overstory is dominated by *Larix lyallii* and varying amounts of *Abies lasiocarpa, Pinus albicaulis,* and *Picea engelmannii.* The undergrowth varies, with *Vaccinium scoparium* and *Luzula hitchcockii* usually present and often dominant.

Pinus albicaulis-Abies lasiocarpa h.t.'s (PIAL-ABLA; whitebark pine-subalpine fir)

Distribution—PIAL-ABLA h.t.'s constitute a mosaic of timberline sites, reduced to insignificant acreages in northern Idaho compared to surrounding regions with extensive high-elevation areas. The plural designation denotes variation in tree undergrowth composition; individual h.t.'s are not described for want of adequate data and the lack of need to meet broad-based management applications.

Vegetation—*Abies lasiocarpa, Pinus albicaulis,* and *Picea engelmannii* occur in varying proportions, often as groveland clusters; with increasing elevation, the spacing between groves increases as does crown deformation due to the effects of wind and snowpack. *Abies* and *Picea* are stunted (<55 to 60 ft [16 to 18 m]), may approach a shrub-like form, and reproduce principally by layering of lower branches.

Usually a notable undergrowth difference exists between (1) windward and dry sites dominated by grasses, *Juncus parryi*, and scattered forbs; and (2) lee slopes and moist sites (heavy snowpack), characterized by *Arnica latifolia, Vaccinium scoparium, Luzula hitchcockii,* and north of the Nez Perce NF by the heath plants *Phyllodoce empetriformis* and *Cassiope mertensiana.*

Steele and others (1981) have noted for central Idaho that excessive sheep use is reflected in contour ribbons composed of *Juncus parryi*, and in the case of severe degradation and erosion, by dominance of *Polygonum phytolaccaefolium.*

Productivity/Management—Timber potential is very low because of slow growth rates, low basal areas, and poor bole form. Watershed potential is apparently high, as is

esthetic appeal. The fragile nature and slow vegetational recovery time of these sites dictates dispersed, low-impact recreation.

Other Studies—This vegetation complex was originally described by Daubenmire and Daubenmire (1968). Pfister and others (1977) in Montana, and Steele and others (1981) in central Idaho, have extended the known area of this complex of types.

Abies grandis (ABGR) Series

Distribution—The inland maritime climate and its moderating effects, with which the distribution of *Abies grandis* is correlated, is sufficiently strong to support *A. grandis* throughout the study area. *Abies grandis* is the indicated climax species beyond the geographical and ecological limits of the more shade-tolerant and moisture-dependent *Thuja plicata* and *Tsuga heterophylla* (Minore 1979). The *A. grandis* series area of importance is confined to the Nez Perce and southernmost Clearwater NF's. Further north the series is restricted, relative to the area occupied by the *Thuja* and *Tsuga heterophylla* series, occurring on relatively warm exposures and excessively drained substrates. The *A. grandis* series grades to the *Pseudotsuga menziesii* series on drier, warmer sites and to the *Abies lasiocarpa* series on cooler sites. The elevational range of the *A. grandis* series is greatest in the southern portion of the Clearwater River drainage, from <1,500 to 6,300 ft (460 to 1,920 m). To the north 250 mi (416 km) in northern Boundary County, *A. grandis* as a series is relegated to specific edaphic or topographic conditions; as a species, it ranges from valley floors (1,800 ft [550 m]) to approximately 5,100 ft (1,555 m).

See Distribution section of ABLA series for a discussion of the separation of the *A. grandis* from the *A. lasiocarpa* series.

Vegetation/Fire— Steele and others (1981) note the ABGR series to be floristically the most diverse of all central Idaho series; whereas in northern Idaho it shares this distinction with the *T. plicata* series (absent in central Idaho). The relatively moderate climate is associated with high species diversity. Both climate and flora are transitional, respectively, between Pacific maritime and continental, and between Central Rocky Mountain and Northern Rocky Mountain. Ostensibly, there is greater environmental diversity (three h.t.'s) for the series at its eastern limits in Montana (Pfister and others 1977) and southern limits in central Idaho (six h.t.'s, Steele and others 1981) when compared to the Daubenmires' (1968) one h.t., ABGR/*Pachistima myrsinites*, in northern Idaho. This disparity is explained by the Daubenmires' limited data set (10 stands) that underrepresented environmental diversity for northern Idaho and resulted in lumping of distinct environments where data were inadequate to assess the variability represented. Our more intensive sampling for the series (250 stands) led to partitioning of the environmental spectrum into 15 taxonomic units, a number more in accord with the diversity expected from a tree series' geographic center of importance (Cooper and Pfister 1984).

The ABGR series supports no unique undergrowth species assemblages; rather, its composition bears an affinity to the undergrowths of the *A. lasiocarpa*, *Pseudotsuga*, *T. plicata*, and *T. heterophylla* series. A diverse high-coverage shrub component (*Acer glabrum*, *Ceanothus* spp., *Amelanchier alnifolia*, *Rubus parviflorus*, *Holodiscus discolor*, and *Symphoricarpos albus*) may be present on early successional stages with their coverages generally decreasing with age (increasing tree canopy coverage), even on the warmest exposures. Forb species range from those characteristic of saturated soils (for example, *Senecio triangularis* and *Athyrium filix-femina*) to those typical of steppe sites (for example, *Balsamorhiza sagittata*).

On moist sites, *A. grandis* is a major recolonizer and canopy dominant even following severe site disturbances. However, because of slower initial establishment and growth it usually forms a subordinate layer to seral trees. *Pseudotsuga*, which also has slower initial growth than its common seral associates, is the major seral species on nearly all *A. grandis* h.t.'s. The predominance of *Pseudotsuga* in our data, however, may be a bias introduced by sampling older stands. Distribution of other seral species is differentiated by region and h.t., but their relative abundance may be more a consequence of stand history and age than site characteristics (Antos and Habeck 1981; Cattelino and others 1979). Mixtures of *Picea engelmannii* and *Pinus contorta* generally occur on colder h.t.'s, whereas *Pinus ponderosa* is prevalent only on the warmer types and phases. *Larix occidentalis* can be a major component where fire has been a significant influence, but overall its occurrence is notably sporadic relative to its distribution in northwestern Montana (Pfister and others 1977). It is virtually absent from whole drainages where the local climate seems favorable. *Pinus monticola* occurs scattered on the Clearwater NF and northward; it is seldom a stand dominant.

Multiple-pathway successional models developed by Antos and Habeck (1981) for Montana's Swan Valley, more general ones by Kessel and Fischer (1981) and Cattelino and others (1979), and a seral stages classification for the ABGR/VAGL h.t. (Steele and Geier-Hayes 1982) indicate that a wide variety of seral communities can develop on a given ABGR h.t., depending on an interaction of initial composition, seed source, type and degree of disturbance, and time since stand initiation. According to the Antos and Habeck (1981) model, a local scarcity of *L. occidentalis* (cited above) may result from fires recurring at intervals shorter than required for *L. occidentalis* to develop its highly fire-resistant bark. The implications of the short life expectancy (120 to 160 years) and rapid canopy breakup of *P. contorta* stands are several: (1) mixed stands (*P. contorta-L. occidentalis*) that burn prior to significant *P. contorta* mortality will be replaced by stands with a higher proportion of *P. contorta*; (2) heavy fuel beds are produced, increasing the probability of intense fires and resulting in the dominance of *P. contorta*, especially toward the center of large burns; (3) repeated fires at intervals of less than 100 to 150 years favor *P. contorta* but significantly longer intervals (>160 years) tend to eliminate this species and favor *L. occidentalis*, *Pseudotsuga*, and *A. grandis*.

On the Nez Perce and Clearwater NF's, periodic fires have been a major influence and have resulted in site domination by *P. ponderosa* and *Pseudotsuga* on warm, dry sites and *P. contorta* on colder sites. Throughout northern

Idaho, *A. grandis* h.t.'s have registered repeated underburns that maintained open, seral-species forests prior to 1900 (Arno 1980). Extremely high coverages of *Pteridium aquilinum* and *Poa pratensis* can be produced, respectively, by burning and heavy livestock use. Most disturbed areas, depending on the rate of tree canopy development and degree of livestock use, return to native species dominance. Some sites, despite the cessation of disturbance, show negligible recolonization by native species, or at least a continued dominance of *P. pratensis*, *P. aquilinum*, and/or *Rudbeckia occidentalis*.

The best documented succession studies in this series are: (1) Zamora's (1982) regarding broadcast-burned clearcuts and wildfire on the Nez Perce NF, ABGR/PAMY h.t. (corresponding to our CLUN-CLUN, CLUN-XETE, ASCA-ASCA h.t.'s), which spans a 190-year sequence, and (2) that of Steele and Geier-Hayes (1982) of the ABGR/VAGL h.t. in central Idaho. Antos and Habeck (1981) also discuss undergrowth changes following burning on logged sites and stand-replacing fires (ABGR/CLUN and THPL/CLUN h.t.'s). All studies indicate that major changes in undergrowth composition coincide with "tree canopy closure" (Antos and Habeck 1981) or development of "a distinct overstory stratum" (Zamora 1982). This point marks the beginning of the "stagnation stage" of Daubenmire and Daubenmire (1968); shade-intolerant species are eliminated, the shrub stage terminates (in nonshrubby h.t.'s), and changes in undergrowth species are of relative abundance, not loss or displacement. These changes are a function of overstory structure (mostly canopy coverage). Time elapsed until a distinct overstory develops is primarily a function of the rapidity of tree regeneration following disturbance. Antos and Shearer (1980) and Stickney (1982) also discuss plant succession in this series with attention to management implications.

Productivity/Management—Site indexes range from moderate to very high (appendix F), with values from the more moist sites being comparable to those of the THPL series. The diversity of seral trees and their generally high growth rates combine to offer diverse silvicultural opportunities. Site indexes for *A. grandis* are highest on relatively warm, moist sites; here its height growth rate occasionally exceeds those of the seral species. *Pinus ponderosa* is generally the fastest growing tree but is currently important on only the warmest sites, partly because of fire suppression and advancing succession. *Pseudotsuga* is moderately to highly productive in this series and occurs on all but sites having saturated soils. *Picea engelmannii* and *P. contorta* are adapted to wet and cold sites.

Ferguson and Adams (1980) have proposed some silvicultural strategies that follow from their model of *A. grandis* response (height growth) after overstory removal. Their model indicates that, in addition to physical site variables, habitat type is an important response predictor. Generally, *A. grandis* on ABGR series sites is not suitable for release unless certain mitigating conditions are met. A regeneration model applicable to the ABGR series that is based on silvical characteristics of Northern Rocky Mountain tree species, site data, and stratified by habitat type and treatment, has been developed as a submodel of the Prognosis Model (Ferguson and others 1986; Stage 1973).

Reforestation of h.t.'s on which succession favors shrubfields, *Rudbeckia occidentalis* or *Pteridium* glades, or *Calamagrostis rubescens* swards may require thorough site preparation and planting. Early successional stages of some types can produce high-quality browse for elk and deer, with lower elevations and south slopes often being used as winter range. Much of this series in the Palouse and Joseph Plains area, where soils are deep, has been converted to farms and pastures.

Trunk rots, primarily *Echinodontium tinctorium* (Indian paint fungus), may be rampant in *Abies* on moist sites (areas of heavy mortality noted as "heartrot" centers), but are of decreasing incidence on drier sites (Frederick and Partridge 1977). The intrinsically high rates of *E. tinctorium* infestation and increase due to the reactivation of dormant infections by mechanical injury (logging) are major factors arguing against uneven-aged management of *A. grandis* on moist sites (Antos and Shearer 1980). *Poria weirii* and *Armillaria mellea* are the primary root-rot pathogens in the series. Preliminary indications (McDonald 1983) are that the rate and severity of *Armillaria* infestations are associated with groups of like h.t.'s; the more moist, moderate temperature groups are most severely affected (see Grouping section).

Abies grandis/Senecio triangularis h.t. (ABGR/SETR; grand fir/arrowleaf groundsel)

Distribution—ABGR/SETR is a minor h.t., occurring on bottomlands and toe-slopes with high water tables at low to middle elevations (2,600 to 4,600 ft [790 to 1,400 m]) of the *Abies grandis* zone. These sites are beyond the geographic range of *Thuja plicata* and at or below the lower elevational limits of *Abies lasiocarpa*. Adjacent slopes or better drained conditions usually support ABGR/ASCA-ASCA or ABGR/CLUN-CLUN.

Vegetation—*Picea engelmannii* and *A. grandis* are the major colonizing species, but *A. grandis* demonstrates the greater reproductive capacity under heavy shading. In mature stands Ferguson (1985) has noted *A. grandis* and *P. engelmannii* regenerating only on rotting logs and stumps. *Abies lasiocarpa* may occur as a minor climax species at upper elevations or in frost pocket locations. Drier edges of the h.t. support small amounts of *Pseudotsuga menziesii* and *Larix occidentalis*.

The undergrowth is characterized by a diverse assemblage of moist-site forbs, of which *Athyrium filix-femina*, *Trautvetteria caroliniensis*, and *Senecio triangularis* exhibit the highest constancy and coverage.

Productivity/Management—Based on limited data, site indexes for *A. grandis* and *Picea* appear high. As with all high-water-table sites, extreme caution should be exercised in site manipulation. These sites are easily degraded through any disturbance; susceptibility to windthrow may be unusually high. Cutover stands are colonized by *Alnus sinuata*, *Pteridium aquilinum*, and/or *Rudbeckia occidentalis*, making regeneration difficult.

Other Studies—Steele and others (1976) have described this type as ABGR/*Athyrium filix-femina* on the Nez Perce NF. Also using *Athryium* as a diagnostic species, Pfister and others (1977) found this type in canyon bottoms of Montana's Bitterroot Range (denoting it ABGR/CLUN-*Aralia nudicaulis*).

Abies grandis/Asarum caudatum h.t. (ABGR/ASCA; grand fir/wild ginger)

Distribution—ABGR/ASCA is a major h.t. south of the distribution of *Thuja plicata*, reaching its greatest extent on the drainages of the Clearwater River. It occupies all terrain from lower to upper elevations (2,200 to 5,950 ft [670 to 1,815 m]) of the ABGR zone. Some phase distinctions are noted with regard to its topographic, aspect, and elevational distribution. ABGR/ASCA is indicative of environments warmer and more moist than ABGR/CLUN, usually protected exposures or covelike situations. The original data set (Steele and others 1976) from which this type was identified has been considerably augmented, and the originally defined type and phases have been confirmed. On warm but drier sites it merges with ABGR/CLUN h.t.'s; on colder, drier sites it grades to ABGR/XETE or ABLA/CLUN h.t.'s.

Vegetation—Seral tree success is differentiated by phase; only *Pseudotsuga menziesii* is moderately important across all phases. Following disturbance, ABGR/ASCA sites are frequently recolonized by *Abies grandis*, leading to the somewhat atypical case of even-aged stands dominated by a climax species. In mature stands on the Selway Ranger District, Ferguson (1985) has noted that regeneration of *A. grandis* and *Picea engelmannii* is confined to rotting logs and fractured stumps; *Taxus brevifolia* was able to regenerate on the soil surface. The moderate environments of these sites are reflected in high species richness and undergrowth coverages, especially in the forb layer where *Clintonia uniflora, Tiarella trifoliata, Viola glabella*, and *Smilacina stellata* are characteristically present. Only *Asarum caudatum* is diagnostic for the type. Other forbs, *Coptis occidentalis, Disporum hookeri, Polystichum munitum*, or *Syntheris platycarpa*, may occasionally dominate this layer. *Acer glabrum* and *Rosa gymnocarpa* are the only shrubs with high constancy; their coverage declines with increasing stand age and canopy cover. With the exception of one phase, *Xerophyllum tenax* is notably unimportant.

Menziesia ferruginea (MEFE) phase—This phase occurs on the coolest, upper elevation (>4,400 ft [1,340 m]) sites within the h.t., usually confined to steep northwest- through east-facing slopes or benchlands. It grades to ABGR/CLUN-MEFE on drier, less moderate sites and to ABGR/ASCA-TABR or -ASCA phases on warmer sites. A layer of *M. ferruginea* dominates a tall shrub stratum, which may include abundant *T. brevifolia* and *Vaccinium globulare*. Within ABGR/ASCA these sites have the greatest potential for supporting a diversity of seral trees—*Picea engelmannii* and *Pseudotsuga* are the major seral dominants—but *Pinus contorta, Pinus monticola*, and *Larix occidentalis* also occur. *Abies lasiocarpa* can be a minor coclimax dominant.

Taxus brevifolia (TABR) phase—To date, this phase has been found exclusively on the Nez Perce NF, concentrated in the western portion of the South Fork Clearwater River drainage. It ranges in elevation from 4,000 to 5,600 ft (1,220 to 1,710 m) and occupies a variety of topographic positions, but is most prevalent on moderate to steep slopes with warm, often protected exposures and ridgetop benches. These sites differ environmentally from those of ABGR/ASCA-ASCA or ABGR/CLUN-CLUN by occurring principally at higher elevations, where they grade to ABGR/CLUN-XETE on more exposed or warmer, drier sites. Employing discriminant analysis, Crawford (1983) has shown thinner A horizons and shallower depth to the BC horizon for his TABR/ASCA h.t. (our ABGR/ASCA-TABR) as contrasted with the ABGR/ASCA h.t. Whether these soil differences are the cause of vegetation patterns or, conversely, register vegetation effects is a moot point.

The very shade-tolerant *T. brevifolia* dominates a tall shrub-small tree layer, becoming so dense in patches that shrubs of lesser stature, herbs, and tree seedlings (except *Taxus*) are virtually eliminated. Generally, *A. grandis* dominates the overstory. *Picea* is the most common of the weakly represented seral trees. Hypothetically, given at least several hundred years with no disturbance, these sites could succeed to monospecific *Taxus* dominance (Crawford and Johnson 1984). Acknowledging that this successional consequence is possible, though improbable, owing to high fire-return frequencies on the Nez Perce NF and windthrow, we have recognized most sites with the potential for developing high coverages of *Taxus* as TABR phases. Nevertheless, some sites supporting high *Taxus* coverages occur in other types and phases (for example, ABGR/ASCA-MEFE, ABGR/CLUN-MEFE, and ABGR/SETR).

Asarum caudatum (ASCA) phase—Description of this, the most moderate phase, generally follows that of the h.t. It ranges from 2,100 to 5,400 ft (640 to 1,645 m) but occurs predominantly below 4,800 ft (1,465 m). It occupies gentle to steep slopes of all aspects, with warmer exposures more frequently represented. It is bordered at lower elevations by the THPL series and on drier or colder sites by other ABGR/ASCA phases or ABGR/CLUN-XETE, -PHMA, or -CLUN phases. Coverages of forbs and warm-site shrubs, such as *Symphoricarpos albus, Holodiscus discolor*, and *Physocarpus malvaceus*, are increased relative to those found on the other phases and persist late into the sere (fig. 35). *Abies grandis* and *Pseudotsuga* generally codominate seral stages. The seral importance of *Picea* is reduced in this phase, while that of *P. monticola, P. ponderosa*, and *L. occidentalis* is increased.

Soils—Parent materials vary, but granitics and metasediments are best represented. Upper horizons of virtually all profiles are influenced by volcanic ash (appendix D). Only traces of exposed soil or rock are found, and gravel content generally did not exceed 30 percent (average 15 percent in upper horizons). Soil textures are primarily silt loams and silty clay loams. About half of the ASCA phase profiles possess a restrictive layer, caused by increases in clay content or a compacted horizon; sites not having this layer are well drained. The effective rooting depth ranges widely, from 9 to 31 inches (22 to 80 cm) averaging 20 inches (50 cm). Throughout the profile soil pH ranges from slightly acid (6.0) to neutral (7.1), averaging 6.3.

Productivity/Management—Site indexes for all species across all phases are high to very high. *Pseudotsuga* and *P. ponderosa* are most successful and fastest growing on lower elevations and warmer exposures within the type (usually the ASCA phase), whereas *Picea* establishes and grows most rapidly on colder sites (MEFE phase) (appendix F). Though most stands appear to be highly produc-

Figure 35—*Abies grandis/Asarum caudatum* h.t.-*Asarum caudatum* phase on a moderate southerly slope (3,800 ft [1,160 m]) south of Mush Saddle in the Clearwater Mountains. Even-aged 80-year-old *Pseudotsuga* dominates the canopy with *A. grandis* slowly establishing in the understory. Undergrowth is dominated by forbs with *Disporum hookeri*, *A. caudatum*, *Smilacina stellata*, and *Coptis occidentalis* well represented. The scattered shrub layer is typical of later successional stages (canopy closure) within this phase.

tive, early site domination by shade-tolerant, tall shrubs (*Menziesia* and *Taxus*) apparently reduces stocking levels (and productivity) throughout the life of the stand. Removal or reduction of the tall shrub layer may be necessary to establish seral conifers. Partial cutting practices can result in the dominance of *A. grandis*; in fact, conditions within the type are so favorable to *A. grandis* that it often regenerates on clearcuts in greater numbers than seral associates and its rate of initial height growth can equal that of seral species.

The TABR and portions of the MEFE phase constitute important winter range for moose (Pierce 1983); they both may also receive appreciable summer and fall use. Silvicultural strategies seeking to maintain *Taxus* stands should consider that it is: (1) extremely shade tolerant but can adjust to the high light intensities following canopy removal; (2) capable of regeneration by sprouting and layering following overstory removal, though its primary dispersal mechanism is animals; and (3) extremely sensitive to fire and sun scalding and, to a much lesser degree, to mechanical damage (Crawford 1983). Overstory removal, especially in the ASCA phase, promotes a dense layer of forbs and shrubs that provides considerable large herbivore forage. ASCA phase sites also constitute that portion of the h.t. with the greatest winter range potential for herbivores other than moose.

Much of this h.t. covers those portions of the Clearwater and Nez Perce NF's where succession on cutover areas leads to dominance by *Alnus sinuata*, *Pteridium aquilinum*, and/or *Rudbeckia occidentalis*; these communities are both long-persisting and intractable to regeneration. Pocket gophers (*Thomomys* spp.) are a major influence in this complex of community types (Neiman and others 1985).

Other Studies—Several of the stands in the Daubenmires' (1968) ABGR/*Pachistima myrsinites* h.t. and at least one stand of ABGR/CLUN of Lillybridge and Williams (1984) ABGR correspond to the ASCA phase of ABGR/ASCA. This h.t. and phases were first described for the Nez Perce NF by Steele and others (1976), and this location and those on the Clearwater NF encompass its reported extent. Crawford and Johnson (1984) have conducted an intensive analysis of *T. brevifolia* dominated stands on the Nez Perce NF and recommend an alternative syntaxonomy, emphasizing the climax status of *T. brevifolia*, for environments we recognize as the ABGR/ASCA h.t.; they conclude alternative syntaxonomies may coexist and that each may have specific information and unique implications for land managers.

Abies grandis/Clintonia uniflora h.t. (ABGR/CLUN; grand fir/queencup beadlily)

Distribution—ABGR/CLUN is a broadly distributed major h.t. that increases in importance from the Kaniksu NF southward to the Nez Perce NF. South of the Middle Fork Clearwater River drainage it is the dominant mid-montane h.t. In its northern range it occurs on relatively dry exposures; adjacent moist sites belong to the *Tsuga heterophylla* or *Thuja plicata* series, CLUN h.t.'s. In the southern part of its range, where the greatest phase diversity is found, it occupies all exposures on relatively moist sites from 2,000 to 6,100 ft (610 to 1,860 m). Phases are associated with unique combinations of site attributes.

Vegetation—*Abies grandis*, in addition to being the climax dominant, is a major and the most consistent dominant of seral stages, even following clearcutting or severe wildfire. Seral tree success is related to region and phase; only *Pseudotsuga menziesii* is consistently important in all phases.

Undergrowth is characterized by the presence of *Clintonia uniflora* and a variable assemblage of moist-site herbs, including *Smilacina stellata, Galium triflorum, Coptis occidentalis, Bromus vulgaris, Disporum hookeri,* and *Adenocaulon bicolor*. The only shrubs consistently present in all phases, generally with higher coverages in early seral stands, are *Rubus parviflorus, Rosa gymnocarpa, Lonicera utahensis, Vaccinium globulare,* and *Linnaea borealis*, a subshrub.

Menziesia ferruginea (MEFE) phase—The MEFE phase is indicative of the coldest sites within the type, grading to ABGR/CLUN-XETE and ABGR/CLUN-CLUN on warmer sites and ABLA/CLUN-MEFE on colder sites. It ranges between 4,200 and 6,200 ft (1,280 and 1,890 m) elevation, generally confined to cool northerly exposures, but in cold-air drainages it may extend more than 1,000 ft (305 m) below the usual phase limits. *Picea engelmannii, Pinus contorta,* and *Larix occidentalis* are more, and *Pseudotsuga* less abundant than in other phases of the h.t. *Abies lasiocarpa* is commonly present. The shrub layer is dominated by *M. ferruginea* and *V. globulare*, and the forb layer by *Arnica latifolia, C. occidentalis,* and *Xerophyllum tenax*, or even *Viola orbiculata* (fig. 36). On the Nez Perce NF, *Taxus brevifolia* may be an important, sometimes dominant, component of the tall shrub layer.

Taxus brevifolia (TABR) phase—This phase is found on the Nez Perce NF, concentrated primarily in the western portion of the South Fork Clearwater River drainage. It ranges from 3,400 to 5,800 ft (1,035 to 1,770 m) and occupies moderate to steep slopes with warm, though often protected, exposures. These sites differ environmentally from ABGR/CLUN-CLUN sites by occurring principally at higher elevations; 80 percent of ABGR/CLUN-TABR stands were found between 5,000 and 5,600 ft (1,525 and 1,710 m) whereas 80 percent of ABGR/CLUN-CLUN stands occurred between 3,000 and 5,200 ft (915 and 1,585 m). Abiotic site conditions are also quite similar to those of ABGR/CLUN-XETE. Steele and others (1976) hypothesized that an unknown soil condition may explain the difference between the stands wherein *Taxus* is abundant (and characteristic for the phase), and surrounding vegetation (fig. 37). Crawford (1983) could not demonstrate statistically significant differences in abiotic variables (including soil conditions) between TABR/CLUN (our ABGR/CLUN-TABR) and ABGR/CLUN (all other phases) though his ABGR/CLUN-TABR sites tend to have thicker A horizons and greater potential solar insolation loads.

Abies grandis dominated the overstory in all observed successional stages, with *Picea, Pseudotsuga,* and *L. occidentalis* relatively equally represented as minor seral species. Only in the densest *Taxus* patches is forb coverage and species richness reduced; even under less than the highest density conditions, conifer seedlings (other than those of the extremely shade-tolerant *Taxus*) may be totally eliminated. *Coptis occidentalis, V. orbiculata,* or *A. latifolia* may dominate the forb layer. *Linnaea borealis* is well represented as a subshrub. Crawford (1983) proposed a *T. brevifolia* series for these sites; we have not incorporated the *Taxus* series into this classification, largely for practical considerations (see discussion of ABGR/ASCA-TABR h.t.).

Xerophyllum tenax (XETE) phase—Found from the Kaniksu to the Nez Perce NF, the XETE phase is most prevalent on the eastern portion of the Clearwater and Nez Perce NF's. These sites are environmentally intermediate between warmer CLUN phases and the colder and drier ABGR/XETE h.t., or comparable h.t.'s in the ABLA series. More than 75 percent of the stands occurred on southeast- through west-facing slopes, and 90 percent were found between 4,000 and 5,750 ft (1,220 and 1,750 m), with extremes to 3,350 and 6,000 ft (1,020 and 1,830 m). *Pseudotsuga* is the major seral dominant. *Larix occidentalis, Picea, P. contorta,* and *P. monticola* may be present, but in amounts generally much reduced relative to *Pseudotsuga*. *Pinus ponderosa* may occur as scattered individuals. Undergrowth differs from other CLUN phases by the dominance of *Xerophyllum* in a forb layer of reduced cover and species diversity (fig. 38). *Vaccinium globulare* dominates the shrub layer.

Physocarpus malvaceus (PHMA) phase—This phase occupies the warmest, driest portion of the h.t. It is found from the Kaniksu NF southward on well-drained sites between 2,200 and 4,800 ft (670 and 1,460 m). Ranging from east- to west-facing slopes, it predominates on exposed south-facing slopes. The PHMA phase borders on several series and h.t.'s but was most noted grading to THPL/CLUN-CLUN, ABGR/XETE, or ABGR/CLUN-CLUN on more moist sites, or ABGR/PHMA on drier sites. Following major disturbance, *Pseudotsuga* is the leading seral conifer, with *A. grandis* sometimes slow to reestablish. *Picea* and *A. lasiocarpa* are notably absent. *Larix* and *P. contorta* are sporadically represented, and *P. ponderosa* is more abundant than in other phases. Undergrowth is dominated by the shrubs characteristic of the phase—*Physocarpus malvaceus* and *Holodiscus discolor*—with high coverages, especially in early seral stages, of *Acer glabrum, Amelanchier alnifolia, Rosa gymnocarpa, Symphoricarpos albus,* and *Rubus parviflorus* (fig. 39). Despite the high shrub coverages, herb coverages and diversity are not notably reduced from modal h.t. conditions; however, *Tiarella trifoliata* is conspicuously absent.

Figure 36—*Abies grandis/Clintonia uniflora* h.t.-*Menziesia ferruginea* phase on a moderate northwest slope (4,340 ft [1,325 m]) west of the Red River Ranger Station. The shrub layer is dominated by *M. ferruginea*, *Vaccinium globulare*, and *V. scoparium*. Herbaceous layer canopy cover is greater than normal due to significant canopy reduction through *Pinus contorta* mortality in this 120-year-old stand currently dominated by *Pseudotsuga*.

Figure 37—*Abies grandis/Clintonia uniflora* h.t.-*Taxus brevifolia* phase on a gentle south aspect (4,850 ft [1,480 m]) on the Horse Creek Research Natural Area north of Elk City, ID. In this 100-year-old stand *T. brevifolia* is just attaining a tree size stature, the largest being 6 inches d.b.h. (15 cm) and 25 to 30 feet (7 to 9 m) tall. *Xerophyllum tenax* dominates the undergrowth with relatively high coverage considering the two superimposed tree layers.

Figure 38—*Abies grandis/Clintonia uniflora* h.t.-*Xerophyllum tenax* phase on a moderately steep southeastern exposure (4,280 ft [1,305 m]) just south of Elk City, ID. Typical for this phase, the overstory is dominated by even-aged *Pseudotsuga* and *Pinus contorta*; *Abies grandis* is establishing slowly, mostly in gaps created by *P. contorta* mortality. *Xerophyllum tenax* is so dense that overlapping tussocks give the impression of a grassy sward.

Figure 39—*Abies grandis/Clintonia uniflora* h.t.-*Physocarpus malvaceus* phase on a gentle southwest exposure (3,210 ft [975 m]) just south of the Pend Oreille River; stand has experienced at least two underburns since establishment following stand-replacing wildfire. *Pseudotsuga*, *Pinus ponderosa*, and *Larix* characterize the overstory with the undergrowth of *Abies grandis* slowly establishing in canopy gaps. The undergrowth is dominated by a tall shrub layer (including *Physocarpus malvaceus*, *Holodiscus discolor*, and *Acer glabrum*); of the 20 herbaceous species, none exceed 1 percent coverage.

Clintonia uniflora (CLUN) phase—This phase predominates on the Nez Perce and Clearwater NF's, but occurs sporadically as far north as the Kaniksu NF. The observed elevational range was 2,200 to 5,350 ft (670 to 1,630 m); 75 percent of the stands were located below 4,000 ft (1,220 m). This phase represents modal environments within the h.t.; they are transitional (considering core area only) between the warmer-more moist ABGR/ASCA-ASCA and TABR phases, the cooler MEFE phase, and the cooler, drier XETE phase. In the northern portion of its range, the CLUN phase occurs on warm exposures or excessively drained sites; south in its range it is found more broadly distributed on benches, stream terraces, and toe-slope to midslope positions, usually of low to moderate slope, and all but northerly exposures.

Pseudotsuga and *A. grandis*, together or singly, dominate seral stages. Other seral species—*P. ponderosa*, *P. contorta*, *P. monticola*, *Larix*, and *Picea*—are weakly represented, especially considering the moderate site conditions and their importance in this phase in contiguous studies (Pfister and others 1977; Steele and others 1981). *Abies grandis* approaches monospecific dominance within approximately 250 to 300 years following stand initiation. Undergrowth composition generally follows the type description. *Vaccinium globulare* increases in importance on cooler exposures, and *L. borealis* is common throughout this phase, being best represented on benches and warmer toe-slopes. *Coptis occidentalis*, *S. stellata*, and *C. uniflora* dominate the forb layer (fig. 40).

Soils—The following description considers the modal CLUN-CLUN phase with exceptions noted by phase. Parent materials vary widely and include limestone, a relatively rare substrate in northern Idaho (appendix D). Ash-influenced soils are relatively rare in the CLUN phase, but ash is prevalent in about one-third of the plots in other phases (lack of ash in our CLUN-phase sites may result from a biased sample, primarily Nez Perce NF plots). Soil textures are predominantly loams, silt-loams, and clays, but range to loamy sands. Gravel content of surface horizons ranges from zero to 60 percent, averaging between 15 and 20 percent for all phases but MEFE, which has a value of less than 5 percent. MEFE phase gravel content increases sharply with increasing depth. Clay pans developing at depths greater than 20 inches (50 cm) constitute restrictive layers on about one-third of the XETE phase. Effective rooting depth varies widely, from 7 to 31 inches (18 to 80 cm), averaging 16 inches (40 cm); the relatively deep average rooting depth (24 inches [60 cm]) of the MEFE phase may be related to low gravel content. Surface and subsurface soil pH ranges, respectively, from 5.6 to 6.5 (average 6.0) and 5.5 to 6.2 (average 5.9); soils of the TABR phase appear to be more basic (pH values to 7.2).

Figure 40—*Abies grandis/Clintonia uniflora* h.t.-*Clintonia uniflora* phase on a bench (3,280 ft [1,000 m]) north of Orofino, ID. The undergrowth is dominated by a rich forb layer (predominantly *Coptis occidentalis*, *Smilacina stellata*, *Cornus canadensis*, and *C. uniflora*). Following clearcutting nearly 100 years ago *Abies grandis* and *Pseudotsuga* (and fewer numbers of *Pinus monticola* and *P. contorta*) established and are now between 120 and 150 ft (36 and 46 m) in height.

Productivity/Management—Timber productivity and species suitability for management are related to phase; however, the type in general is highly productive (appendix F) and affords a wide latitude in silvicultural prescriptions. On a portion of this h.t. Daubenmire (1961) found *P. ponderosa* height growth was rapid for 50 to 60 years. After approximately age 60, though, growth tapered off, resulting in higher site index values for *P. ponderosa* growing on PSME/PHMA and PIPO/PHMA h.t.'s (at index age of 100 years).

Site indexes for the ABGR/CLUN phases floristically comparable to ABGR/ASCA phases show a trend of reduced values for all species jointly represented (appendix F). The warmer ABGR/CLUN phases, PHMA, CLUN, and even XETE, on the basis of limited data, appear to be prime sites for *P. ponderosa*. *Abies grandis*, *Pseudotsuga*, and *P. contorta* are easily regenerated on clearcuts, with their response varying according to phase. The moderate nature of these sites should be favorable for *Larix*, but insufficient data exist to evaluate its potential. Many of the sites sampled for site index were beyond the geographic concentration of *P. monticola*, accounting for its being underrepresented in appendix F. Most ABGR/CLUN sites, except those of the PHMA phase, appear, on the basis of vegetative composition and site parameters, capable of supporting good *P. monticola* growth.

The TABR phase, for which meager data exist, is floristically and environmentally most similar to ABGR/ASCA-TABR and may respond similarly to management. Overstory removal in both h.t.'s results in a marked seral shrub and forb increase and burning may result in a sward of *Pteridium aquilinum*. Reduction of the *Taxus* layer will be necessary to achieve stocking with seral conifers. Regarding *Taxus* Crawford (1983) indicated that: (1) mortality following overstory removal is due, not to solarization, but to mechanical injury from logging, (2) tractor piling of slash could cause severe losses, and (3) it is extremely intolerant of fire and any attempt at slash disposal and site preparation through broadcast burning would cause its virtual elimination. *Taxus* response to manipulation is an important consideration because it is a very significant component of moose winter forage (Pierce 1983). Its high coverages in the west-central Nez Perce NF are considered responsible for concomitantly high moose populations. Uneven-aged management may be the most feasible approach to preserving *Taxus* and harvesting timber, but will probably result in the dominance of *A. grandis*, the value of which is severely reduced by a high incidence of Indian paint fungus (*Echinodontium tinctorium*) and root rot.

Little is known concerning the MEFE phase, but it seems to produce *Picea* and *P. contorta* of high site index. Partial cutting, especially in the MEFE and PHMA phases, may result in a lack of tree regeneration under an increased shrub cover. Clearcutting and stand-replacing wildfire in these two phases can result in dramatic increases in shrub coverages; therefore immediate planting would seem advisable where reforestation is a prime management objective.

All phases produce abundant elk and deer forage, especially in earlier successional stages. Low-elevation phases with southerly aspects, principally CLUN and PHMA, are utilized as elk and deer winter range. Browse production can be enhanced by broadcast burning of slash following clearcutting or seedtree cuts. The warmer phases of this h.t. potentially support *Pteridium* glades, which constitute a loss in browse production and a long-persisting impediment to tree regeneration. Under these conditions, site preparation may be limited to mechanical scarification; if steep slopes dictate burning then planting should immediately follow site disturbance. Consult the management section of ABGR/ASCA concerning the impact of regeneration and site preparation techniques on *Taxus*. Livestock find little forage on stocked sites, whereas early successional stages may constitute productive transitional range. Kingery (1983) indicates that livestock use of these sites during early regeneration stages may be detrimental to planted stock.

Zamora (1982) and Pyke and Zamora (1982) discuss some important management implications regarding succession within the Daubenmires' (1968) ABGR/*Pachistima myrsinites* h.t. (Zamora's plots correspond mainly to our CLUN-CLUN and CLUN-XETE phases). They show an inverse, nearly linear relationship between tree canopy and undergrowth coverages. But the most intense effects of tree-undergrowth interaction do not occur until at least 25 years following cutting. This interval may be considerably extended because it is a function of the rate of post-disturbance tree establishment. Until trees seed in, become established, and overgrow the shrub layer, there is little effect of trees on shrubs. Broadcast-burned clearcuts attain maximum shrub and forb productivities (2,320 to 2,680 lb/acre [2,600 to 3,000 kg/ha]), within 13 to 17 years following disturbance (Zamora 1982).

Other Studies—All the stands in the Daubenmires' (1968) ABGR/PAMY h.t. correspond to phases of our ABGR/CLUN and ABGR/ASCA h.t.'s, predominantly CLUN-CLUN and ASCA-ASCA. ABGR/CLUN (including several of the same phases described herein) has been described for northwestern Montana (Pfister and others 1977), central Idaho (Steele and others 1981), the Nez Perce NF (Steele and others 1976), and northeastern Washington (Lillybridge and Williams 1984).

Abies grandis/Linnaea borealis h.t. (ABGR/LIBO; grand fir/twinflower)

Distribution—ABGR/LIBO is a minor h.t. sampled on the Nez Perce NF, in the Purcell Trench and also observed on the southern Clearwater NF. It is more extensive in central Idaho (Steele and others 1981), where three phases are distinguished. ABGR/LIBO is found on lower to middle elevations of the *Abies grandis* series, ranging from 2,200 to 5,300 ft (670 to 1,615 m) on protected and gentle slopes and benches. As noted by Pfister and others (1977), this type replaces ABGR/CLUN to the east and south of the zone most influenced by the Inland Maritime climatic regime.

Vegetation—All stands sampled were a mix of seral tree species. *Pseudotsuga menziesii* and *Pinus ponderosa* were most abundant, followed by *Pinus contorta* and *Picea engelmannii*. *Larix occidentalis* is a minor seral component, but with a favorable stand history it is capable of site dominance.

Linnaea borealis is common to abundant and *Calamagrostis rubescens* usually forms a scattered layer. Some stands support a diverse forb assemblage, but generally sparse coverages and lack of mesic-site species is the pattern. Other vegetation features vary according to phase.

Xerophyllum tenax (XETE) phase—The XETE phase is found at higher elevations (>4,900 ft [1,490 m]), usually on southerly aspects, where it grades to the drier ABGR/XETE h.t. The undergrowth is dominated by *X. tenax* over which is superimposed a layer of *Vaccinium globulare*. *Pinus contorta* and *Pseudotsuga* are the primary seral species.

Linnaea borealis (LIBO) phase—The LIBO phase is found most frequently on benchlands or gentle topography. In the northern portion of its range, this phase is associated with coarse outwash materials whereas adjacent sites on finer textured soils usually support TSHE or THPL series habitat types. *Pinus ponderosa* is increased in importance and *Picea* decreased relative to the XETE phase. The undergrowth is likely to be dominated by *C. rubescens* in earlier successional stages, but crown closure limits its cover in more mature stands.

Soils—Very limited data indicate slightly acidic, gravelly depositional soils with shallow ash horizons (appendix D). Only trace amounts of exposed soil and rock are found. Effective rooting depth varies between 8 and 18 inches (21 and 45 cm).

Productivity/Management—Site index data are extremely limited, even from adjacent areas; hypothetically, productivity should be moderate to high (Steele and others 1981), somewhat less than on ABGR/CLUN or ABGR/ASCA h.t.'s. Site indexes on the more moderate LIBO phase are assumed to be higher than on the XETE phase. Opportunity for mixed stand establishment following fire or clearcutting appears good.

Although the usually gentle terrain may attract livestock, it is primarily the early seral stages that provide forage. Browse potential is greater, too, for big game early in the sere (Steele and others 1981).

Other Studies—ABGR/LIBO (XETE and LIBO phases) has been identified by Pfister and others (1977) in western Montana; however, its centers of importance are probably northeastern Oregon (Hall 1973) and west-central Idaho (Steele and others 1981). Some stands within the ABGR/VACA association (Lillybridge and Williams 1984) are environmentally and floristically similar to our ABGR/LIBO-LIBO.

Abies grandis/Xerophyllum tenax h.t. (ABGR/XETE; grand fir/beargrass)

Distribution—ABGR/XETE occurs mainly on the eastern Nez Perce and southeastern Clearwater NF's and extends into contiguous portions of Montana and central Idaho. It is very sporadically distributed as far north as the southern Kaniksu NF. Indicative of the cool-dry limits of the *Abies grandis* series, it therefore is usually found between ABGR/LIBO and *Abies lasiocarpa* series h.t.'s and may grade to ABGR/CLUN-MEFE or ABLA/MEFE on colder, more moist exposures. ABGR/XETE occurs from 4,200 to 6,500 ft (1,280 to 1,980 m), predominantly on east- to west-facing slopes.

Vegetation—*Pseudotsuga menziesii* and *Pinus contorta* are the most important seral species. *Pinus ponderosa, Picea engelmannii,* and *Larix occidentalis,* in decreasing order of importance, occur in mixed-species stands. *Abies grandis* is occasionally slow to reestablish, reflecting relatively dry and frosty conditions within the type.

Xerophyllum tenax and *Vaccinium globulare* dominate the undergrowth, with other undergrowth characteristics determined by phase.

Coptis occidentalis (COOC) phase—The COOC phase represents more moderate conditions within the h.t., often bordering ABGR/CLUN-XETE or less frequently ABGR/LIBO. *Pseudotsuga* is the primary seral tree species, with lesser amounts of *L. occidentalis* and *P. contorta* also present. The forb layer, usually dominated by *C. occidentalis,* and in which *Anemone piperi, Goodyera oblongifolia, Viola orbiculata,* and *Thalictrum occidentale* are highly constant, is richer than that of XETE phase (fig. 41).

Figure 41—*Abies grandis/Xerophyllum tenax* h.t.-*Coptis occidentalis* phase on a midelevation (4,820 ft [1,470 m]) bench south of Fish Creek Meadow Campground on the Nez Perce NF. *Abies grandis, A. lasiocarpa,* and *Picea engelmannii* share overstory dominance in the 170-year-old stand. *Vaccinium globulare* is the scattered midsize dominant shrub superimposed on a dense layer of *V. scoparium,* which obscures a diverse forb layer dominated by *Anemone piperi.*

Xerophyllum tenax (XETE) phase—The XETE phase characterizes colder, drier, more exposed sites within the h.t.; the most extreme sites are indicated by *Vaccinium scoparium* (fig. 42). Warmer sites or those in early seral stages may support a sward of *Calamagrostis rubescens*. Seral tree importance follows the h.t. description, except for *P. contorta*, which increases relative to its COOC phase representation.

Soils—Because all plots with soil pits occurred on the Nez Perce and southern Clearwater NF's, the parent materials are nearly exclusively granitics and gneiss; quartzite and shale are also represented (appendix D). Surface soils are mainly fine textured (loams and silt loams averaging 15 percent gravel) over coarser subsurface soils (sandy loams and sands averaging 20 percent gravel). No restrictive layers were found, and ash deposits were found only in the moist COOC phase. Surface and subsurface pH values are moderately to slightly acidic, averaging 6.2.

Productivity/Management—Site index values range from moderate to high for *Pseudotsuga*; other seral trees have a comparable range (appendix F). Given adequate seed sources, mixed species stands should naturally regenerate following clearcutting with site preparation. Planting *L. occidentalis* where historic factors (for example, catastrophic fires) may have eliminated it, or in areas beyond its **apparent** geographic limits (portions of the Nez Perce NF) seems warranted on a test basis.

Figure 42—*Abies grandis*/*Xerophyllum tenax* h.t.-*Vaccinium globulare* phase on a ridgetop bench (5,240 ft [1,595 m]) east of the Red River Ranger Station. Even-aged 100-year-old *Pinus contorta* dominates the site with *A. grandis* slowly reestablishing. Though *X. tenax* dominates the undergrowth, high coverages (>50 percent in this stand) of *Vaccinium scoparium* accompanying scattered *V. globulare* are indicative of a colder microclimate for the phase as found primarily on the Nez Perce NF.

In Montana, on the ecologically comparable but colder, less mesophytic ABLA/XETE-VAGL h.t., Arno and others (1985) have modeled tree and undergrowth succession for treatments of varying intensities. Their results illuminate the disturbance response of northern Idaho's ABGR/XETE and ABLA/XETE h.t.'s. Salient points of their study are: (1) If slash or site receive no treatment or are broadcast burned full stocking requires >15 years; following wildfire or site scarification regeneration time is half that of untreated stands. (2) Extreme scarification is the treatment most likely to produce "doghair" *P. contorta* stands. (3) *P. contorta* dominates following all treatments. (4) *Pseudotsuga* usually becomes a mature forest stage codominant 100 to 125 years after disturbance (the ubiquity of *P. contorta* is reduced in the ABGR/XETE type) and the overstory dominant following *P. contorta*'s demise. (5) Planting is generally either superfluous or unsuccessful.

These sites are used spring through fall by elk and deer; in some stands *Xerophyllum* flowering heads are totally consumed and *V. globulare* is heavily hedged. *Vaccinium globulare* in adjacent stands may be virtually untouched, possibly an indication of palatability differences or simply a result of proximity to established game trails. Livestock use was not observed in mature stands and potential for such is low. Arno and Simmerman (1982) have found heavy use by cattle on scarified clearcuts produces a persistent, weedy flora in place of native species.

Other Studies—ABGR/XETE was described by Pfister and others (1977) in Montana (only western portions of the Bitterroot and Lolo NF's), by Steele and others (1976) for the Nez Perce NF, and by Steele and others (1981) as an incidental central Idaho h.t.

Abies grandis/Vaccinium globulare h.t. (ABGR/VAGL; grand fir/blue huckleberry)

Distribution/Vegetation—This is an incidental h.t. for northern Idaho, noted in reconnaissance only in the Seven Devils Mountains; the considerable importance of this h.t. in central Idaho is emphasized by its selection for successional modeling (Steele and Geier-Hayes 1982). ABGR/VAGL characterizes the cool extremes of the ABGR series beyond the distributional limits of *Xerophyllum tenax*. *Pinus contorta, Pseudotsuga menziesii*, and *Picea engelmannii* are the predominant seral trees.

Productivity/Management—Site indexes are generally high (Steele and others 1981) with *Picea* and *Pseudotsuga* having the highest values. Seral stands provide important cover and forage for elk and white-tailed deer.

Other Studies—The ABGR/VAGL h.t. was originally described for central Idaho by Steele and others (1981). In Oregon's Blue Mountains, portions of Hall's (1973) white fir-big huckleberry community type (c.t.) are similar to ABGR/VAGL.

Abies grandis/Physocarpus malvaceus h.t. (ABGR/PHMA; grand fir/ninebark)

Distribution—This is a relatively minor but broadly distributed type, occurring throughout northern Idaho. Its observed elevational range was from 2,200 ft (670 m) on the Kaniksu NF to 4,600 ft (1,400 m) on the Nez Perce NF, with most stands occurring from 2,400 to 4,300 ft (730 to 1,310 m). One of the driest ABGR h.t.'s, ABGR/PHMA occurs almost exclusively on southeast through west slopes except at lowest elevations. On drier slopes it merges with PSME/PHMA and on more moist or cooler exposures with ABGR/XETE, ABGR/CLUN-PHMA, ABGR/CLUN-XETE, or ABGR/SPBE.

Vegetation—Even in older stands (100 to 200 years), *A. grandis* may not be well represented because these sites are near its environmental limits as well as those of *Pinus contorta, Larix occidentalis*, and *Pinus monticola*. Further reducing *Abies* representation on these types of sites is a past history of frequent underburning (Hall 1977). *Pseudotsuga menziesii* and *Pinus ponderosa*, in that order, are the important and long-persisting seral species.

Undergrowth is dominated by a variable combination of the characteristic tall shrubs *Physocarpus malvaceus, Holodiscus discolor*, and *Acer glabrum*. Other shrubs with high constancies and coverages (that decline with increasing stand age and tree cover) are *Symphoricarpos albus, Amelanchier alnifolia*, and *Berberis repens*. Forbs present with high constancy are *Smilacina stellata, Osmorhiza chilensis, Galium triflorum, Anemone piperi, Adenocaulon bicolor*, and *Bromus vulgaris*. *Calamagrostis rubescens* is often well represented and may dominate the herb layer of early seral stands.

Coptis occidentalis (COOC) phase—The COOC phase occupies moister and cooler sites within the h.t. and is more prevalent on the Nez Perce and Clearwater NF's. Common (>1 percent) canopy coverages of *C. occidentalis* are diagnostic. The diversity and coverage of forbs is higher than in the PHMA phase; notable among mesic site forbs are *S. stellata, Disporum hookeri*, and *Polystichum munitum*. *Pseudotsuga* is apparently the major seral species. The unexpected lack of other seral tree species in this, the more moist of the two phases, probably reflects the small sample size (6 plots versus 20 for the PHMA phase) and PHMA-COOC's restricted geographic representation, at or beyond the limits of *P. monticola* and *L. occidentalis*.

Physocarpus malvaceus (PHMA) phase—This phase is associated with the drier, lower elevation limits of the type—those environments transitional to the PSME series. *Calamagrostis rubescens* and *Carex geyeri* may constitute a dominant herb layer in young or open stands, but the high shrub (and tree) cover that develops in later seral and mature stands effectively reduces the graminoid component. High-constancy forbs that are also occasionally well represented include *G. triflorum, A. bicolor, Osmorhiza chilensis*, and *Smilacina racemosa*.

Soils—Granite and mica schist dominate the parent materials that included rhyolite, quartzite, argillites, and basalts (appendix D). Ash layers are uncommon though some profiles were loess influenced. Most soils are fine textured, with loams and silt loams predominating. Gravel content is highly variable but most values ranged from 25 to 55 percent; surface rock and bare soil occur in trace amounts. Somewhat less than half of the PHMA phase plots exhibit a restrictive layer usually associated with the rockiness of glacial till or clay pan development in basalts. Effective rooting depth averages 19 inches (48 cm), rang-

ing from 10 to 28 inches (25 to 70 cm). Surface soil pH values spanned a relatively narrow range (6.1 to 7.1, average 6.4) while subsurface pH ranged widely (4.8 to 7.2).

Productivity/Management—Site indexes (appendix F) range from moderate to very high for all seral and climax species, but stand compositions indicate that *Pseudotsuga*, and especially *P. ponderosa*, should be favored for reforestation. Overstory removal will permit shrubs to develop a dense, long-persisting layer that competes with establishing tree seedlings. Burning the site will often result in site occupancy by *Ceanothus* spp. or *Pteridium aquilinum*.

For elk and deer, ABGR/PHMA constitutes important winter range and thermal and yearlong hiding cover, especially in earlier seral stages. Livestock use of these sites is usually nil, except in early seral stages; use at this time can produce heavy *Poa pratensis* coverages as described by Daubenmire and Daubenmire (1968) for PSME/PHMA.

Other Studies—ABGR/PHMA, or a nearly identical taxon, has been described in northeastern Washington (as ABGR/*Holodiscus discolor* association) by Lillybridge and Williams (1984). ABGR/PHMA is similar in vegetative composition and management considerations to the PHMA phase of ABGR/*Acer glabrum* described by Steele and others (1981) for central Idaho, but does not occupy the cool exposures they describe.

Abies grandis/Spiraea betulifolia h.t. (ABGR/SPBE; grand fir/white spiraea)

Distribution/Vegetation—ABGR/SPBE is a minor type representing the warm, dry extremes of the ABGR series. Only in central Idaho and the southwestern Nez Perce NF do individual stands constitute appreciable acreages on benchlands and steep south- to west-facing slopes, otherwise it occurs as a fringe on more moist ABGR/PHMA and ABGR/CLUN h.t.'s. During reconnaissance we found it occurs as far north as the Kaniksu NF and at elevations from 2,800 to 5,200 ft (850 to 1,585 m), but undoubtedly it extends to the lower elevational limits of the ABGR series (<1,600 ft [<485 m]).

Abies grandis is slow to reestablish on these sites, almost all of which have been maintained in seral *Pseudotsuga menziesii* and *Pinus ponderosa* through recurrent underburning. *Pinus contorta* may be an important seral tree on the exceptional benchland occurrence of the type. *Spiraea betulifolia*, *Symphoricarpos albus*, and *Rosa gymnocarpa* dominate the low shrub layer; *Calamagrostis rubescens* increases with disturbance and may also form a discontinuous layer in mature stands. More moist sites within the type support *Smilacina stellata*, *Galium triflorum*, and *Disporum hookeri*.

Soils—Very limited data indicate relatively deep (18 to 26 inches [45 to 65 cm]), effective rooting on these well-drained, moderately gravelly (20 percent average), and slightly acid soils (appendix D). Ash cap depths are highly variable, from a trace to 24 inches (60 cm).

Productivity/Management—Extrapolating from the central Idaho classification (Steele and others 1981) and limited data from this study (appendix F), timber productivity should range from moderate to high. Site indexes tentatively appear higher for *P. ponderosa* than associated species; however, Steele and others (1981) observed *A. grandis* to have exceptionally good growth on these sites under optimum stocking. Site preparation to attain adequate stocking is indicated where *Calamagrostis* sod is present.

Generally, steep terrain and low forage productivity should discourage livestock use; however, these sites may have substantially greater potential for wild ungulate use.

Other Studies—The description of Steele and others (1981) indicates central Idaho (western portion) to be the center of importance for the type; in Oregon's Blue Mountains, the "mixed conifer-pinegrass c.t." of Hall (1973) is quite similar in vegetation and habitat.

Pseudotsuga menziesii (PSME) Series

Distribution—Throughout northern Idaho, *Pseudotsuga menziesii* exhibits a very broad environmental amplitude. Rehfeldt (1978) reports two ecotypes for northern Idaho: one from cool environments mostly above 5,000 ft (1,525 m) elevation, and the other from warmer environments at lower elevations. Plant associations dominated by this species are very limited in far northern Idaho, becoming more extensive and important to the east (Pfister and others 1977), south (Steele and others 1981, 1983), and west (Lillybridge and Williams 1984; Hall 1973). *Pseudotsuga*-dominated associations range from 2,000 to 6,400 ft (610 to 1,950 m) elevation in northern Idaho, with the majority located between 2,500 and 3,700 ft (760 and 1,130 m). All aspects, slopes, and landforms are represented, but our data show a tendency for this h.t. to occupy the warm-dry, moderately steep, south-southwest aspects at midslope on minor ridges.

Vegetation—In northern Idaho, *P. menziesii* occurs as the climax dominant in a narrow environmental zone between *Pinus ponderosa* on drier sites and *Abies grandis* on more moist sites. As a seral species, *Pseudotsuga* is found in all series except *P. ponderosa*. The predominant seral tree species of the *Pseudotsuga* series is *P. ponderosa*. Some early successional stages on more moist sites within this series may be dominated by *Larix occidentalis* or *Pinus contorta*. Isolated individual *A. grandis* may be scattered within the more moist environments of this series, but investigation of their distribution usually shows them to be associated with microsites. Understory vegetation varies from savannalike, bunchgrass-dominated forest to grassy-sward-dominated open forest to dense tall shrubs and closed canopy forest.

Fire—A vast majority of the stands sampled in this series show signs of past fire; probably all stands have been subjected to cool underburns. Fire intervals averaged 7 to 25 years prior to 1900 (Arno 1980). Very few stands sampled have an age greater than 150 years, possibly indicating a cyclic period for conflagration at that rate. If fires were both frequent and hot enough to remove *P. menziesii* and adjacent seed sources, burned sites within this series may appear to be *P. ponderosa* climax. Other sites may have experienced cool surface fires at 7- to

8-year intervals with no subsequent stand replacement occurring for long periods.

Productivity/Management—Productivity for this series varies from low to moderate and is reflected in the undergrowth composition, which ranges from bunchgrass to shrub dominance. As in the *P. ponderosa* series, bunchgrass-dominated *Pseudotsuga* associations are susceptible to severe infestation by dwarf mistletoe (*Arceuthobium* spp.). Silvicultural treatments must take this into consideration, along with the damage that can result from western budworm (*Choristoneura occidentalis*) and Douglas-fir beetle (*Dendroctonus pseudotsugae*) infestations. In stands relatively free of insect and disease infestations, and where *Pseudotsuga* is the desired regeneration species, a selection or shelterwood treatment is recommended; partial shade for seedlings is often necessary on these relatively harsh sites. For sanitation of a stand or to favor *P. ponderosa* or *L. occidentalis* regeneration, a clearcut with thorough site preparation and planting of desired species should be used.

The PSME series is the driest environment in which *Armillaria mellea* (laminated root rots) damage conifers and may prove to be the driest sites on which *Armillaria* can occur (McDonald 1983). Initial results indicate *Armillaria* to be restricted to the moistest environments within this series, with major occurrence and damage in the ABGR, THPL, and TSHE series.

As in the *P. ponderosa* series, light year-round use of shrubs by deer should be beneficial for tree growth (Kosco and Bartolome 1983). Three to 5 years following plantation establishment, light controlled grazing by domestic livestock has been shown to aid timber productivity by reducing herbaceous and woody species competition (Currie and others 1978; Wheeler and others 1980). Initial results from a study currently being conducted in PSME/PHMA and wetter h.t.'s indicate no damage to plantation seedlings in PSME/PHMA from light to moderate livestock grazing the same year as planting (Kingery 1983). Some damage to seedlings does appear to become a problem when similar livestock use is allowed in the *Abies grandis* or *Thuja plicata* series.

Pseudotsuga menziesii/Physocarpus malvaceus h.t. (PSME/PHMA; Douglas-fir/ninebark)

Distribution—PSME/PHMA is the most widely occurring *Pseudotsuga menziesii* h.t. in northern Idaho. On the dry side, this h.t. is normally adjacent to PSME/SYAL, PIPO/SYAL, or PIPO/PHMA and on the moist side adjacent to ABGR/PHMA or PHMA phase of ABGR/CLUN. PSME/PHMA generally occurs on southeast to west aspects of low to moderate slopes at elevations between 2,000 and 3,700 ft (600 to 1,130 m), but is not restricted to these environments.

Vegetation—*Pinus ponderosa* is the major seral tree species in this h.t.; some sites, mostly from the Clearwater NF north, are capable of supporting *Larix occidentalis*. Physiognomy of the overstory is relatively closed forest, with canopy cover ranging from 70 percent to over 100 percent. The understory shrub layer is dominated by *Physocarpus malvaceus* and *Holodiscus discolor*, which singly or combined have a canopy coverage of 25 percent to much greater than 100 percent. Other commonly found shrubs in this h.t. are *Amelanchier alnifolia, Philadelphus lewisii, Rosa gymnocarpa, Spiraea betulifolia*, and *Symphoricarpos albus*. The PSME/PHMA h.t. has increased coverage of *Arenaria macrophylla, Arnica cordifolia, Fragaria* spp., and *Bromus vulgaris* compared to other h.t.'s in this series. Shrub and herbaceous species composition remains relatively constant for all phases.

Smilacina stellata (SMST) phase—The SMST phase occurs throughout the range of this h.t. and represents the wettest environment on which *P. menziesii* is the climax dominant. *Larix occidentalis* and *P. ponderosa* maintain codominance on some of these sites into late seral stages. Diagnostic characteristics of the phase are the presence of *Disporum hookeri* or common coverages (≥1 percent) for *Smilacina stellata, Galium triflorum*, or *L. occidentalis*. This phase has an increased constancy and coverage of mesophytic species (*Osmorhiza chilensis, Thalictrum occidentale, Arenaria macrophylla*, and *Anemone piperi*) compared to the drier PHMA phase (fig. 43). *Carex geyeri* and *Calamagrostis rubescens* may form a sod in seral stands, but their coverage is usually significantly reduced under mature canopies.

Physocarpus malvaceus (PHMA) phase—This phase represents drier and warmer sites of PSME/PHMA and occurs throughout northern Idaho, generally along the westernmost forested portion. *Pinus ponderosa* is the major seral species; *L. occidentalis* is never more than an accidental in this phase. Characteristics diagnostic of the PHMA phase are the lack of or very reduced coverage of species diagnostic in the SMST phase. High coverages of *C. geyeri* and/or *C. rubescens* may dominate the understory on some sites (fig. 44), but the predominant undergrowth composition is moderate to tall shrubs and dry-site forbs.

Soils—Soil parent materials are mainly basalt and quartzite for the SMST phase, with granitics, loess, and volcanic ash also occurring on PHMA phase sites (appendix D). Textures are generally silt-loam to silty clay-loam in the SMST phase, with a broader textural range, gravelly sandy loam to clay-loam, in the PHMA phase. Total depths vary from 8 to 39 inches (20 to 100 cm), with SMST sites tending to have deeper soils. For all phases, pH ranges between 5.5 and 6.6. Bare soil seldom occurs and rock occasionally has up to 25 percent exposure. Litter depth averages 2 inches (5 cm).

Productivity/Management—Productivity for this h.t. is moderate, with the SMST phase having higher site indexes and total basal area than the PHMA phase (appendix F). The two highly competitive graminoids, *C. geyeri* and *C. rubescens*, may cause reduced tree growth in either phase. Sites having a thick moss cushion over basalt talus are essentially unsuitable for intensive management due to unworkable soils.

Reforestation problems can be significant on this h.t.; for central Idaho, Steele and Geier-Hayes (1983) found contour trenching followed by planting to be the only consistently successful technique. With site preparation that effectively controls early site dominance by shrubs and the highly competitive graminoids, all even-aged silvicultural techniques show promise for regenerating highly productive stands of *P. ponderosa*. Uneven-aged techniques

Figure 43—*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.-*Smilacina stellata* phase on a gentle northwest-facing ridge shoulder (3,000 ft [915 m]) north of Moscow, ID. *Pinus ponderosa* and *P. menziesii* codominate the overstory. The tall shrub layer towering over the meter pole is dominated by *P. malvaceous* and *Holodiscus discolor* (its white pyramidal inflorescence reflecting the sun). *Symphoricarpos albus* and *Spiraea betulifolia* form a dense lower shrub layer that obscures the rich forb layer.

Figure 44—*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.-*P. malvaceus* phase on a moderately steep south-facing slope (3,080 ft [940 m]) with coarse-textured soils on Snow Creek west of Bonners Ferry, ID. *Pinus ponderosa*, *P. contorta*, and *Pseudotsuga* codominate the overstory. Note that *P. malvaceous* and *Holodiscus discolor*, while dominating the shrub layer, have much reduced coverage and robustness relative to that shown in figure 43. *Calamagrostis rubescens* (foreground) forms a dense sward; no other herb is present in more than trace amounts.

should give satisfactory results if *P. menziesii* is the preferred species. On the SMST phase, *L. occidentalis* should be considered a potential component for increasing the species mix.

The drier, less-productive PHMA-phase sites within PSME/PHMA may have significant dwarf mistletoe (*Arceuthobium*) infestations. PSME/PHMA-SMST appears to be the driest environment (across all series) on which *Armillaria mellea* root rots damage conifer species (McDonald 1983). Potential for regeneration failure following site disturbance exists due to *Armillaria* inoculum sources remaining onsite.

This h.t. can receive light to moderate seasonal use by cattle without significant damage to advance reproduction or planted stock (Currie and others 1978; Wheeler and others 1980). Significant damage can occur from excessive use as shaded resting areas adjacent to sites having greater forage production. In mature stands wildlife use this h.t. primarily for cover; forage production for elk is low as is palatability of browse species for deer. Seral stages of this h.t. can be very productive for both food and cover requirements of big game.

Other Studies—This h.t. has been described by many other investigators. Daubenmire and Daubenmire (1968) included our two phases in their PSME/PHMA h.t. Hall (1973), Cooper (1975), Pfister and others (1977), Steele and others (1976, 1981, 1983), and Lillybridge and Williams (1984) all describe quite similar plant associations. Successional trends of PSME/PHMA following different disturbances have been described by Cholewa and Johnson (1983) for northern Idaho, Steele and Geier-Hayes (1983) for central Idaho, and Arno and others (1985) for western Montana.

***Pseudotsuga menziesii/Vaccinium caespitosum* h.t. (PSME/VACA; Douglas-fir/dwarf huckleberry)**

Distribution—This h.t. occupies cold (frost pocket) sites within the *Pseudotsuga menziesii* series. It occurs from 2,300 to 4,500 ft (700 to 1,370 m) elevation on low to moderate slopes and all aspects. Its distribution correlates well with soils having well-drained to excessively drained surface horizons, such as found in the glacial tills and outwash material of the Purcell Trench.

Vegetation—*Pinus ponderosa* and *P. contorta* are the seral conifers sometimes dominating these sites for long periods of time. The presence of *Vaccinium caespitosum* with at least common coverage (≥1 percent) of *Arctostaphylos uva-ursi* is diagnostic of this h.t. Generally low coverage of *Spiraea betulifolia*, *Fragaria* spp., and *Calamagrostis rubescens* also characterizes this h.t. On an environmental gradient, PSME/VACA is slightly colder and more moist than PSME/CARU-ARUV. Yet the occurrence of bunchgrasses, such as *Agropyron spicatum*, *Festuca idahoensis*, and *F. scabrella* indicate these sites to be drier and perhaps warmer than the PSME/VACA h.t. described by Pfister and others (1977) or Steele and others (1981).

Productivity/Management—Timber productivity should be moderate for *P. ponderosa*, *P. contorta*, and *P. menziesii* (appendix F). Expect regeneration on mineral soil to be successful, except in frost pocket locations in the Purcell Trench, where a cover crop of *P. contorta* may be required to moderate the microenvironment for seedlings of the other two species. PSME/VACA sites have low forage potential for livestock, and moderate to high potential as winter habitat for deer, elk, and occasionally moose.

Other Studies—Pfister and others (1977) describe PSME/VACA as a major h.t. in Montana; Steele and others (1981) and Ogilvie (1962) list it as incidental in central Idaho and Alberta, respectively. As mentioned, in northern Idaho PSME/VACA appears to be slightly warmer and drier than its description in the above geographic areas. A major portion of PSME/VACCI described by Lillybridge and Williams (1984) for the Colville NF appears quite similar to PSME/VACA as described for northern Idaho.

***Pseudotsuga menziesii/Vaccinium globulare* h.t. (PSME/VAGL; Douglas-fir/blue huckleberry)**

Distribution—This is an incidental h.t. in northern Idaho, occurring mostly on the far eastern edge of the Red River Ranger District of the Nez Perce NF. It tends to occur on south to west aspects above 5,000 ft (1,525 m) elevation. It is much more prevalent in Montana and eastern Idaho, though never a very important h.t. in the Northern Rocky Mountains.

Vegetation—*Xerophyllum tenax* is well represented in the understory, *Vaccinium globulare* can be abundant to missing, and *Calamagrostis rubescens* is normally well represented. Other common shrub and herbaceous associates are *Berberis repens*, *Spiraea betulifolia*, and *Goodyera oblongifolia*.

Productivity/Management—Extrapolating from Montana data, timber productivity of these sites is expected to be low to moderate. *Pinus ponderosa* and *P. contorta* are the common seral tree species and should regenerate on mineral soils. This h.t. can produce significant forage and cover for big game, and berry crops for bears, grouse, and humans.

Other Studies—Pfister and others (1977) describe this as a major h.t. in southwestern Montana; our samples seem to best fit the XETE phase of their PSME/VAGL h.t. Cooper (1975) and Steele and others (1981, 1983) describe this minor h.t. in central and eastern Idaho and western Wyoming.

***Pseudotsuga menziesii/Symphoricarpos albus* h.t. (PSME/SYAL; Douglas-fir/common snowberry)**

Distribution—This is an incidental h.t. in northern Idaho, with all sampled occurrences located south of Orofino. During reconnaissance it was noted in the Palouse occurring as small, usually highly disturbed stands. This h.t. is well represented in central Idaho, Montana, and Wyoming. In northern Idaho, PSME/SYAL occurs on warm, dry, low to middle elevation slopes and benches.

Vegetation—*Pinus ponderosa* is the major seral tree species and often codominates with *Pseudotsuga menziesii* in mature stands. Shrub species, normally low in total coverage, are usually represented by *Symphoricarpos albus*, *Spiraea betulifolia*, *Amelanchier alnifolia*, *Rosa*

gymnocarpa, and *Berberis repens*. The herbaceous layer tends to be rather sparse, with most stands having less than 25 percent total coverage of *Agropyron spicatum*, *Calamagrostis rubescens*, *Carex geyeri*, and associated herbs.

Productivity/Management—Timber productivity, extrapolating from western Montana data, is expected to be low to moderate; however, based on limited data for northern Idaho, this h.t. appears to be considerably more productive (appendix F). *Pinus ponderosa* should regenerate and grow well, whereas *P. menziesii* may prove difficult to regenerate on all but the most moist sites. *Calamagrostis rubescens* sod may develop following disturbance, causing further regeneration difficulty. Forage and browse production on this h.t. is relatively low.

Other Studies—Daubenmire and Daubenmire (1968) originally described this type from stands in eastern Washington. Pfister and others (1977), Steele and others (1981), Hall (1973), and Lillybridge and Williams (1984) describe similar plant associations, but most of these appear to be drier and less productive.

Pseudotsuga menziesii/Spiraea betulifolia h.t. (PSME/SPBE; Douglas-fir/white spiraea)

Distribution—This is an incidental h.t. in northern Idaho; all sampled locations are in the Selway-Bitterroot Wilderness. It usually occupies dry southerly exposures at mid to upper elevations.

Vegetation—These are open stands, with codominance of *Pseudotsuga menziesii* and *Pinus ponderosa*. The understory is characterized by a dominance of *Spiraea betulifolia* in the low shrub layer and *Agropyron spicatum* in the herbaceous layer.

Productivity/Management—Timber productivity of these sites is expected to be low to moderate. *Pinus ponderosa* should be the preferred species due to ease of regeneration and higher yields, compared to *P. menziesii*. Use of this h.t. by livestock and wildlife can be high.

Other Studies—The modal description for this h.t. comes from central Idaho (Steele and others 1981) where it commonly occurs. Adjacent areas have also recognized this h.t. (Pfister and others 1977; Steele and others 1983).

Pseudotsuga menziesii/Calamagrostis rubescens h.t. (PSME/CARU; Douglas-fir/pinegrass)

Distribution—This incidental h.t. for northern Idaho has two phases that tend to occupy spatially (and environmentally) disjunct sites. The moderate- to high-elevation CARU phase generally occurs on steep south-facing slopes above 4,500 ft (1,370 m), while the lower elevation ARUV phase occurs on low to moderate slopes, all aspects, and on glacial drift in and adjacent to the Purcell Trench at elevations of 2,300 to 4,500 ft (700 to 1,370 m). This h.t. occurs in significant amounts outside of northern Idaho (see Other Studies below).

Vegetation—*Pseudotsuga menziesii* is the major species in near-climax stands, with very old seral remnants of *Pinus ponderosa* or *Larix occidentalis* occasionally codominant. *Pinus contorta* is often an early, and occasionally long-persisting, seral dominant. Understory vegetation is generally dominated by a sward of *Calamagrostis rubescens*, with other shrub and forb species being less than abundant (<25 percent coverage). The two phases of this h.t. are identified by *Arctostaphylos uva-ursi*'s presence (ARUV phase) (fig. 45) or absence (CARU phase); also distinctive is the 100 percent constancy and well-represented coverages of *Carex geyeri* in the CARU phase and virtual absence in ARUV.

Productivity/Management—Site index values are generally moderate due primarily to the cold environment and excessively drained soils. *Pinus ponderosa* on the ARUV phase shows the best growth potential within the h.t. With the exception of sites supporting high densities of the very palatable bunchgrass *Festuca scabrella*, forage mature stands produce little for wild and domestic ungulates. Early and midseral conditions, however, should produce a tall shrub component useful as browse and cover.

Other Studies—In the Northern Rocky Mountains, PSME/CARU appears to be the most widely distributed PSME series h.t. In-depth descriptions of the type as it occurs in areas adjacent to northern Idaho can be referenced in Ogilvie (1962), Brayshaw (1965), Daubenmire and Daubenmire (1968), McLean (1970), Stringer and LaRoi (1970), Hall (1973), Cooper (1975), Pfister and others (1977), Steele and others (1981, 1983), and Lillybridge and Williams (1984). Steele and Geier-Hayes (1984) detail successional patterns and management implications for this h.t. in central Idaho.

Pseudotsuga menziesii/Carex geyeri h.t. (PSME/CAGE; Douglas-fir/elk sedge)

Distribution—This h.t. is incidental in northern Idaho, occurring in minor amounts on the Nez Perce NF. It occupies dry, generally south aspects at mid to upper elevations.

Vegetation—*Pinus ponderosa* and *Pseudotsuga menziesii* normally codominate on these open, parklike stands. The undergrowth is dominated by graminoids *Carex geyeri*, *Agropyron spicatum*, and *Festuca idahoensis*.

Productivity/Management—Productivity should be low to moderate, with *P. ponderosa* the most productive and easily regenerated species. Forage production for livestock and elk is site-dependent and variable.

Other Studies—This is a major h.t. in central Idaho and is thoroughly described by Steele and others (1981). In western Montana, however, this is a minor, slightly different h.t. becoming more abundant east of the Continental Divide (Pfister and others 1977). Hall (1973) describes a similar plant community in eastern Oregon.

Pseudotsuga menziesii/Festuca idahoensis h.t. (PSME/FEID; Douglas-fir/Idaho fescue)

Distribution—This is an incidental h.t. in northern Idaho, occurring in only minor amounts on the Nez Perce NF. It is normally located at lower timberline on north and east aspects, being replaced by the drier PIPO/FEID h.t. on south and west aspects. The PSME/FEID h.t. is much more common in central Idaho and west-central Montana.

Figure 45—*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.-*Arctostaphylos uva-ursi* phase on a coarse-textured soil lacking an ash cap and developed from glacial drift in the Hoodoo Lake vicinity of the Purcell Trench (2,290 ft [700 m]). *Pinus ponderosa* dominates the overstory of this multiple-aged stand in which *Pseudotsuga* is slowly regenerating. The dominant herb is rhizomatous *C. rubescens* and the conspicuous bunchgrass is *Festuca scabrella*; only *A. uva-ursi* among the other undergrowth species is more than poorly represented.

Vegetation—*Pinus ponderosa* usually codominates with *Pseudotsuga menziesii*. This condition differs from Montana, where *P. ponderosa* is unrepresented in the PSME/FEID h.t. The undergrowth has few characteristic shrubs and forbs. *Festuca idahoensis* and *Agropyron spicatum* generally codominate the herb layer, but only the well-represented coverage of *F. idahoensis* is diagnostic for the h.t.

Productivity/Management—Timber productivity of PSME/FEID is expected to be low to very low due to both poor height growth and low stockability. Low regeneration success is a further silvicultural consideration. In good range condition this h.t. is relatively productive (800 lb/acre [896 kg/ha] [McLean and others 1971]) for livestock forage in early summer and wildlife habitat during winter months.

Other Studies—This h.t. has been described in British Columbia (McLean 1970), Montana (Pfister and others 1977), and central Idaho (Steele and others 1981); central Idaho's PIPO phase of PSME/FEID seems to best fit our sites.

Pseudotsuga menziesii/Agropyron spicatum h.t. (PSME/AGSP; Douglas-fir/bluebunch wheatgrass)

Distribution—PSME/AGSP is an incidental h.t. in northern Idaho; its occurrence appears to be limited to the Salmon River drainage and possibly lower portions of the Clearwater River drainage. It is best developed in southern portions of central Idaho and central Montana. It occupies steep south to west aspects below 3,000 ft (910 m) and either borders on PIPO/AGSP or constitutes the lower timberline ecotone transitional to bunchgrass steppe vegetation. At its cool, moist extremes, PSME/AGSP grades to PSME/FEID, PSME/SPBE, or PSME/SYAL.

Vegetation—Widely spaced *Pseudotsuga menziesii* and *Pinus ponderosa* are overstory codominants, with generally sparse undergrowth vegetation. Rhizomatous or caespitose *Agropyron spicatum* dominates the grass cover; *Festuca idahoensis* is often a minor component. Other high-constancy herbs are *Achillea millefolium*, *Balsamorhiza sagittata*, and *Pteridium aquilinum*. The presence of *Pteridium* is indicative of past disturbance by fire and grazing.

Productivity/Management—Timber productivity of PSME/AGSP is expected to be low due to both height growth far below the PSME series average and low stockability; poor regeneration success is a further silvicultural problem. Forage production is generally low (5-year average of 400 lb/acre [448 kg/ha]) (McLean and others 1971); the less steep sites are used for livestock grazing only in the spring. In some areas PSME/AGSP does serve as winter and spring habitat for big game and occasionally wild turkey.

Other Studies—Similar descriptions of PSME/AGSP exist for British Columbia (McLean 1970), Montana (Pfister and others 1977), central Idaho (Steele and others 1981), eastern Washington (Daubenmire and Daubenmire 1968; Lillybridge and Williams 1984), and northeastern Oregon (Hall 1973).

Pinus contorta (PICO) Series

Distribution/Vegetation—The PICO series, a minor one in northern Idaho and apparently confined to the Nez Perce and Clearwater NF's, is characterized by essentially pure stands of *Pinus contorta* in which there is no clear indication that another tree species is potentially climax. Areas of nearly exclusive *P. contorta* dominance can be traced to several factors (Pfister and others 1977), listed in order of their decreasing influence in northern Idaho: (1) sites where frequent, widespread, stand-replacing wildfire has eliminated seed sources of shade-tolerant competitors (PICO seral); (2) sites where tolerant competitors are removed through frequent light ground fires (PICO seral); (3) sites with excessively dense stands that competitively exclude regeneration of shade-tolerant competitors (PICO seral); and (4) sites that are intrinsically unsuitable for regeneration and establishment of other conifers (PICO climax).

Pfister and Daubenmire (1975) indicate that *P. contorta* occupies a climax dominant position on sites having particular topoedaphic features, but cite no examples for the Northern Rocky Mountains. On portions of the Nez Perce NF and possibly other locations in northern Idaho, one *P. contorta* community (PICO/VASC) does occupy sites that appear to be unsuited for the regeneration and establishment of other conifer species, and thus we have recognized this condition as a habitat type. Shallow, moisture-deficient soils appear to be the controlling environmental factor for this edaphic climax. It is hypothesized that these conditions are a result of either (or both) (1) major wildfires and subsequent surface soil erosion, or (2) chance distribution of volcanic ash, found well-mixed with soils of other sites, that missed being deposited on or was eroded from these sites. These conditions are associated with reduced soil fertility and increased moisture stress.

Sites where *P. contorta* is self-perpetuating are typically well-drained to excessively drained uplands with gentle topography (Moir 1969; Despain 1983). They are similar environmentally to the colder portions of the *Pseudotsuga menziesii* series and drier portions of the *Abies* spp. series. The PICO series is extensive in eastern Montana (Pfister and others 1977) and central Idaho (Steele and others 1981) where *P. contorta* functions primarily as a seral conifer. PICO community succession in northern Idaho within the ABGR, ABLA, THPL, TSHE, or TSME zones will normally proceed to site dominance by one of these climax species. The rate of succession on these sites is inversely proportional to the size, frequency, and intensity of disturbance. Areas of *P. contorta* seral dominance should classify, through the presence of mesic undergrowth associations, to one of the above-cited series. Two PICO c.t.'s have been delineated; field identification and management of these long-term *P. contorta*-dominated sites is facilitated by recognizing them as distinct seral types.

Note that not all *P. contorta*-dominated stands belong in this series. Where dense, stagnated stands have prevented or reduced the regeneration of competitors, observation of nearby stands having very similar site characteristics, particularly soil depths and parent materials, and an adequate seed source should allow one to determine the successional status and climax species for these sites.

Ecology/Fire—Some special ecological conditions, most of which occur on a very limited basis in northern Idaho, favor *P. contorta*. It is well adapted to cold-air drainage (Heuser 1969), fluctuating water tables (Tarrant 1953), soils at both ends of the spectrum of drainage conditions (Stephens 1966), and soils that develop on locally unique parent materials (Youngberg and Dahms 1970; Pfister and others 1977; Despain 1973, 1983). On the southern portion of the Nez Perce NF, coarse granitic (lacking ash cap) and glacial detritus substrates, coupled with severe microclimates of high elevations, seem capable of producing environments sufficiently unique to favor *P. contorta* to the virtual exclusion of its competitors.

Most of the nearly pure *P. contorta* populations of northern Idaho appear to have resulted from postfire succession as evidenced by even-aged stand structure and omnipresence of abundant soil charcoal. However, as in stands of central Idaho where *P. contorta* appears to be self-perpetuating (Steele and others 1981), those of northern Idaho have nonserotinous cones, sparse undergrowth, widely spaced trees, and light fuels. All these conditions are atypical for ecosystems where fire is a significant evolutionary factor and point to unique substrate conditions as the controlling factor in distribution of climax *P. contorta*.

Productivity/Management—Timber productivity is expected to be low to moderate. *Pinus contorta* is the obvious choice for management; some lower elevation sites (<6,200 ft [1,890 m]) may support unthrifty *Pseudotsuga*.

The gentle terrain provides easy access and opportunity for recreation. These sites receive light to moderate use by elk and deer during the summer and fall.

Other Studies—Many studies (Moir 1969; Pfister and Daubenmire 1975; Pfister and others 1977; Steele and others 1981, 1983; Despain 1983) have recognized *P. contorta* c.t.'s or h.t.'s and associated their distribution with environmental conditions, particularly gentle terrain coupled with edaphic factors that are unsuitable for the regeneration of other conifers.

Pinus contorta/Vaccinium caespitosum c.t. (PICO/VACA; lodgepole pine/dwarf huckleberry)

Distribution/Vegetation—PICO/VACA c.t. is locally represented in the higher valley floors of the Nez Perce NF, especially in the Red River Valley and Dixie vicinity. It occurs at mid to lower elevations of the *Abies lasiocarpa* zone on gentle or undulating topography, where cold-air ponding creates frost pockets; usually these are positions of glacial drift deposition and coarse textured soils.

Vaccinium caespitosum forms a patchy dwarfed shrub layer often accompanied by *Calamagrostis rubescens*. Regeneration of climax tree species is so sporadic that relating these sites to the ABLA series or the cold portion of the PSME series is problematic.

Productivity/Management—Stands of PICO/VACA are best managed as ABLA/VACA (see Pfister and others 1977; Steele and others 1981), with *P. contorta* the only suitable timber species. Timber productivity appears to be midway between PICO/VASC h.t. and ABLA series h.t.'s.

Other Studies—This c.t. has been described by Pfister and others (1977) and Steele and others (1981).

Pinus contorta/Xerophyllum tenax c.t. (PICO/XETE; lodgepole pine/beargrass)

Distribution/Vegetation—PICO/XETE is an incidental type; it has been observed only on the Nez Perce NF at mid to upper elevations of the *Abies lasiocarpa* zone. Soils of these sites are thin, granitic, and generally lack an ash layer. These sites can be distinguished from PICO/VASC sites by having soils generally deeper than 16 inches (40 cm) and an average litter depth of 2 inches (5 cm).

Vaccinium scoparium or *V. globulare* dominates the undergrowth. *Xerophyllum tenax* tussocks are widely spaced and other forbs (*Arnica* spp., *Lupinus* spp.) are sparse. The highest elevation sites support *Luzula hitchcockii* and *Pinus albicaulis*, and are transitional to ABLA/XETE-LUHI and ABLA/LUHI h.t.'s. In most cases this c.t. represents a long-persisting seral stage of ABLA/XETE or, more infrequently, ABGR/XETE.

Productivity/Management—For timber production, stands of PICO/XETE c.t. can be managed as the ABLA/XETE h.t. (colder phases), with *P. contorta* the most favored species.

Other Studies—This c.t. has been previously described by Steele and others (1976) for portions of the Nez Perce NF. A similarly named but richer c.t. was described by Volland (1976) for TSME and ABLA sites of central Oregon.

Pinus contorta/Vaccinium scoparium h.t. (PICO/VASC; lodgepole pine/grouse whortleberry)

Distribution/Vegetation—PICO/VASC is the only *Pinus contorta*-dominated community recognized as climax (h.t.) in northern Idaho. It is an incidental h.t. occurring mainly in southern and eastern portions of the Nez Perce NF at mid to upper elevations of the *Abies lasiocarpa* zone. Excessively drained shallow soils are especially characteristic of these sites. Elevations range from 5,000 to 6,000 ft (1,520 to 1,830 m); aspects from southeast to west.

In both the overstory and understory *P. contorta* is virtually the only tree species represented. Individuals in the overstory exhibit poor height growth; none had site index values exceeding 42. Individuals in the understory are severely stunted and are normally the same age as the stand dominants. What few shade-tolerant tree species are present in the understory are extremely stunted, not merely suppressed, and appear incapable of responding to release following thinning or overstory removal. Regeneration of all tree species following initial stand establishment is essentially nonexistent; self-perpetuation of *P. contorta* is sporadic, favored by mortality-created canopy gaps.

The undergrowth is dominated by a layer of *Vaccinium scoparium*; other shrubs are very sparse. *Xerophyllum tenax, Chimaphila umbellata, Calamagrostis rubescens*, and *Carex concinnoides*, all with low coverages, are the only consistently represented herbaceous species (fig. 46). Very seldom do more than 12 species occur in a 1/10-acre (0.04-ha) plot.

Soils—The soils are highly diagnostic for this h.t. They are exceptionally shallow, with depth to parent material usually less than 8 inches (20 cm) and not exceeding 12 inches (30 cm), and always excessively well drained. Parent materials are granitic or mica schist, and the coarser fragments are predominantly quartz. Textural classes range from coarse sandy loam to loam, while pH ranges from 5.8 to 6.1. No ash caps were found, but minor amounts of ash are mixed in the upper horizons. Average litter depth is 0.5 inch (1.5 cm).

Productivity/Management—*Pinus contorta* is the only timber species adapted to this h.t. Productivity is very low; natural 100-year-old stands produce trees averaging 60 ft (18 m) in height and 8 to 11 inches (20 to 28 cm) d.b.h. (average site index of 36). Regeneration problems may result on highly disturbed sites.

Other Studies—A climax *P. contorta* c.t. has not previously been described for northern Idaho. A PICO/VASC h.t. was recognized by Hoffman and Alexander (1976, 1980) in Wyoming's Big Horn Mountains and Colorado's Routt NF (as PICO/*Shepherdia canadensis*). Various studies have described PICO/VASC as a c.t. generally seral to ABLA/VASC (Hall 1973; Moir 1969; Pfister and others 1977; Steele and others 1981, 1983; Volland 1976).

Figure 46—*Pinus contorta/Vaccinium scoparium* h.t. on a moderate southeast-facing slope (5,650 ft [1,720 m]) along Whitewater Ranch Road, Nez Perce NF. *Pinus contorta* is the only successfully reproducing tree; very stunted *Abies lasiocarpa* occur as accidentals. The species-poor undergrowth is dominated by *V. scoparium* and *Calamagrostis rubescens*, with *Xerophyllum tenax* present as scattered clumps. Soils are shallow (<12 inches [30 cm]).

Pinus ponderosa (PIPO) Series

Distribution—Pure stands of *Pinus ponderosa* are a minor component of the forested vegetation in northern Idaho. It is the climax dominant overstory species on the western edge of northern Idaho's driest forested zone at elevations generally below 4,000 ft (1,220 m). In the loessal soils of the Palouse region of northern Idaho, many of the currently *P. ponderosa*-dominated stands are actually seral to *Pseudotsuga menziesii*; therefore sites must be classified with special care. Eastward along the major river drainages between Moscow and Riggins, *P. ponderosa* occupies a narrow environmental strip between steppe vegetation and more mesic *Pseudotsuga menziesii* forests. It occurs in a broad range of canopy densities, from closed forest to very open savanna. The ability to rapidly elongate the root system in an environment of high moisture deficiency is the primary competitive advantage *P. ponderosa* has with respect to other tree species of this region (Daubenmire 1968b). This series occurs on all aspects, slopes, and landforms at elevations ranging from 1,000 ft (300 m) to as high as 5,000 ft (1,520 m). Like Daubenmire and Daubenmire (1968), we had difficulty finding relatively undisturbed plant communities representative of this series to sample.

Vegetation—*Pinus ponderosa* is the only tree species capable of growing in this dry environment. *Pinus ponderosa* associations can be segregated into two groups: a shrub- and forb-rich group and a drier bunchgrass-dominated group. The shrub-dominated understory is very similar to the *Physocarpus malvaceus* and *Symphoricarpos albus* h.t.'s of the *P. menziesii* series. The graminoid-dominated sites have understory associations quite similar to the *Agropyron-Festuca* association of Daubenmire (1970) and the *Festuca-Agropyron* association of Tisdale (1979).

Fire—Fire has had varying effects within this series. Prior to 1900, all sites probably experienced cool underburns at 5- to 20-year intervals (Arno 1980). On most sites these fires simply reduced the litter and duff accumulations. On some of the more moist sites, *P. menziesii* regeneration was periodically removed, but with aggressive fire control these "fire climax" *Pinus* sites are succeeding to *Pseudotsuga* site dominance. These sites must be classified with care because although *Pseudotsuga* is the indicated climax, it may never have dominated the site and developed soils characteristic of *Pseudotsuga* h.t.'s.

Productivity/Management—The *P. ponderosa* series is generally the least productive forest land of northern Idaho. On grass-dominated sites, productivity is very low and tree regeneration is very scarce and sporadic. Wildlife and livestock grazing is often the major use of these lands. Shrub-dominated sites are much more productive due not only to increased site index, but also to the site's ability to produce greater basal area (that is, higher stocking rates). Daubenmire (1961) found widespread *Arceuthobium campylopodum* (dwarf mistletoe) infection of trees on bunchgrass-dominated sites but virtually no parasitization of trees on shrub-dominated sites. Steele and others (1981) found infestation in 15 percent of all stands in central Idaho, while Pfister and others (1977) found none in Montana. Silvicultural controls for mistletoe have been outlined by Barrett (1979).

All silvicultural regeneration techniques have been utilized for *P. ponderosa.* Site preparation to reduce competition for soil moisture is recommended on most sites. Sites with shallow soils should not be greatly disturbed because any soil loss may irreparably degrade the site. It may therefore be prudent to forgo harvesting sites with less than 24 inches (61 cm) total soil depth. Due to the infrequent concurrent combination of a good seed crop, adequate site preparation, and a cool, moist spring, natural regeneration should not be extensively relied upon (Barrett 1979; Foiles and Curtis 1973; Harrington and Kelsey 1979; Wellner 1970b). A seed-tree treatment, when coupled with interplanting, may be the most realistic approach, accepting that a prolonged regeneration period is expected.

Light year-round use of shrubs by deer should be beneficial for tree growth (Kosco and Bartolome 1983). Three to 5 years following plantation establishment, light controlled grazing by domestic livestock should aid timber productivity by reducing herbaceous and woody competition (Currie and others 1978; Wheeler and others 1980).

Pinus ponderosa/Physocarpus malvaceus h.t. (PIPO/PHMA; ponderosa pine/ninebark)

Distribution—PIPO/PHMA is very limited in northern Idaho. It has been found only on northwest to northeast aspects of moderate slopes, bordering PIPO/SYAL of hotter, drier southerly exposures and grading to PSME/PHMA on slightly more moist sites. The PIPO/PHMA h.t. is generally found at elevations below 3,000 ft (910 m).

Vegetation—Two shrub layers are characteristic of this h.t. The lower layer, up to 3 ft (1 m) tall, is composed of *Symphoricarpos albus, Spiraea betulifolia, Berberis repens,* and *Rosa* spp. The tall layer, up to 6 ft (2 m), is dominated by *Physocarpus malvaceus* and *Holodiscus discolor,* with other commonly found shrubs being *Ceanothus sanguineus, Philadelphus lewisii, Prunus virginiana,* and *Amelanchier alnifolia.* The herbaceous layer has high constancy for *Galium boreale, Arenaria macrophylla, Osmorhiza chilensis, Erythronium grandiflorum, Fragaria* spp., *Bromus vulgaris, Calamagrostis rubescens,* and *Carex geyeri.* This understory composition is very similar to that found in the PSME/PHMA-PHMA phase.

Soils—Soil parent material is mainly loess, with volcanic ash mixed in the upper horizons. Textures range from silt to silty clay-loam. Total depth ranges between 24 and 32 inches (60 and 80 cm), and pH ranges from 5.8 to 6.6. Bare soil and rock usually do not occur on these deep soil sites. Litter depth averages 1.5 inches (4 cm) and totally covers surface on undisturbed sites.

Productivity/Management—Although timber productivity is low, PIPO/PHMA is still the most productive h.t. within the series (appendix F). Proper stocking levels and control of highly competitive shrub species are important silvicultural considerations in this h.t. Because total site occupancy by native shrubs typically follows disturbance, planting immediately following logging and site preparation is recommended.

Other Studies—This h.t. was originally described by Daubenmire and Daubenmire (1968) for eastern Washington and northern Idaho. Steele and others list PIPO/PHMA as being an incidental h.t. on the Nez Perce NF (1976) and in central Idaho (1981).

Pinus ponderosa/Symphoricarpos albus h.t. (PIPO/SYAL; ponderosa pine/common snowberry)

Distribution—The PIPO/SYAL h.t. occurs sporadically from Coeur d'Alene south along the western forested edge of northern Idaho. It constitutes a narrow strip between the *Festuca idahoensis-Symphoricarpos albus* h.t. (Daubenmire 1970) on drier sites and PIPO/PHMA or PSME/SYAL on more moist sites. Most locations are below 3,500 ft (1,070 m) elevation on moderately steep terrain and on warm, dry southeast to northwest aspects.

Vegetation—Low shrubs dominate this h.t.; *Symphoricarpos albus, Spiraea betulifolia, Berberis repens,* and *Rosa* spp. have the greatest constancy. Some of these sites may also have *Crataegus douglasii, Prunus emarginata, P. virginiana, Amelanchier alnifolia,* and/or *Rhamnus purshiana* as a tall shrub layer. The herbaceous undergrowth of this h.t. is usually sparse and lacking in species diversity, although disturbed sites of this h.t. often have rampant populations of exotic herbs. Daubenmire and Daubenmire (1968) note the presence of *C. douglasii* on relatively moist sites and along river terraces within this h.t. In our area this appears to be a response to past disturbance, or occurs on sites transitional to the steppe community, *Crataegus-Symphoricarpos* (Daubenmire 1970).

Soils—Soil parent materials are typical of the westernmost portion of the study area being mainly loess, basalts, metasediments, and some volcanic ash. Textures are fairly heavy, being silt-loam to silty clay-loam. Total depth ranges from 15 to 35 inches (40 to 90 cm). Bare soil and rock usually do not occur on undisturbed sites. Litter depths average 2 inches (5 cm).

Productivity/Management—Timber productivity in naturally occurring stands of this h.t. is low, but could be improved by means of appropriate stocking levels and control of highly competitive understory vegetation. Although natural regeneration in this h.t. is often successful, once site preparation costs are incurred, early spring planting should be considered so as to ensure prompt site occupancy by tree seedlings.

Other Studies—This h.t. was originally described by Daubenmire and Daubenmire (1968) from sites mostly located in eastern Washington. Steele and others (1976, 1981) describe this h.t. for west-central Idaho, Pfister and others (1977) describe a similar type for Montana, and Johnson and Simone (1986) describe a more productive association for northeastern Oregon.

Pinus ponderosa/Festuca idahoensis h.t. (PIPO/FEID; ponderosa pine/Idaho fescue)

Distribution—PIPO/FEID occurs in minor amounts along the western edge of our forested zone from Coeur d'Alene south. It is most prevalent along the Clearwater, Snake, and Salmon River drainages on sites slightly more moist than in the PIPO/AGSP h.t., but drier than the PIPO/SYAL h.t. It occurs on gentle to steep slopes of east, south, and west aspects. At the northern end of its range in Idaho, PIPO/FEID does not occur above 2,500 ft (760 m) elevation, whereas Steele and others (1981) found it at 5,800 ft (1,770 m) in the Salmon Uplands.

Vegetation—This type has an open, parklike appearance because of the low natural stocking capacity. *Festuca idahoensis* is the dominant grass species, usually found in conjunction with lesser amounts of *Agropyron spicatum* (fig. 47). This h.t. has a richer component of both perennial and annual forbs than is found in the PIPO/AGSP h.t., with increases particularly in coverage of *Balsamorhiza sagittata*, *Achillea millefolium*, and *Eriogonum heracleoides*.

Figure 47—*Pinus ponderosa/Festuca idahoensis* h.t. on a steep south-facing slope with shallow and gravelly soils, in the Dudley Peak vicinity, Coeur d'Alene NF. Overstory of *P. ponderosa* is uneven-aged. *Agropyron spicatum* and *F. idahoensis* are abundant and *Balsamorhiza sagittata* is the only important forb.

Productivity/Management—Timber productivity of this h.t. is low due to both poor individual tree growth and low site stockability. Tree regeneration will be almost as difficult as on the PIPO/AGSP h.t.; both natural and artificial regeneration will have a generally low probability of success. Forage production for domestic and wild ungulates on this h.t. is greater than on PIPO/AGSP; in southern British Columbia McLean and others (1970) measured 700 lb/acre (784 kg/ha) whereas in northeastern Oregon mean herbage production was 360 lb/acre (404 kg/ha) (Hall 1973). Overgrazing and harsh logging treatments can significantly damage soils and thus site productivity.

Other Studies—Daubenmire (1952) originally described this h.t. as a portion of PIPO/AGSP h.t., but later (Daubenmire and Daubenmire 1968) split the two h.t.'s. Our h.t. is similar to the *Pinus ponderosa-Festuca idahoensis* h.t. of McLean (1970), the FEID phase of PIPO/FEID h.t. of Pfister and others (1977), PIPO/FEID h.t. of Steele and others (1981), and ponderosa pine-fescue of Hall (1973) and Johnson and Simone (1986).

Pinus ponderosa/Agropyron spicatum (PIPO/AGSP; ponderosa pine/bluebunch wheatgrass)

Distribution—PIPO/AGSP occurs primarily on steep, south-facing slopes overlooking the Snake and Salmon Rivers. As Daubenmire and Daubenmire (1968) originally identified this h.t. in Spokane County, WA, some examples for northern Idaho may occur on coarse-textured glacial drift to the west of Coeur d'Alene. The Daubenmires also mention its occurrence in the Clearwater River drainage. It appears to be limited to below 4,000 ft (1,220 m) elevation on hot, dry slopes.

Vegetation—A sparse overstory of only *Pinus ponderosa* characterizes the tree layer of this h.t. The bunchgrass or rhizomatous form of *Agropyron spicatum* is the only conspicuous understory species. *Achillea millefolium* and *Balsamorhiza sagittata* are the only consistently present perennials; most other herbaceous species are small, early flowering annuals.

Productivity/Management—This h.t. has very low timber productivity due to both poor individual tree growth and low site stockability. Regeneration of trees, whether naturally or artificially, will have low probability of success; natural site potential will allow only a low basal area stocking level (appendix F). The major resource of these sites is often forage for wild and domestic ungulates. McLean and others (1970) indicate forage production to average 400 lb/acre (448 kg/ha) for the very similar PSME/AGSP association and Hall (1973) found 430 lb/acre (516 kg/ha) for the PIPO/AGSP c.t. Relatively high amounts of forage are available for cattle and elk; browse production for deer and sheep is essentially zero. Season and amount of use by livestock should be regulated if these sites serve as elk winter range.

Other Studies—The PIPO/AGSP h.t. has been described in nearly the same form in several adjacent areas. It was originally described by Daubenmire (1952) and Daubenmire and Daubenmire (1968), and later listed by Steele and others (1981) in central Idaho, and Pfister and others (1977) in Montana. For the northern Blue Mountains Hall (1973) described a ponderosa pine/wheatgrass c.t. without shrubs that appears comparable to our PIPO/AGSP h.t., as did Johnson and Simone (1986). McLean (1970) identified a *Pinus ponderosa-Agropyron spicatum* h.t. for southeastern British Columbia that appears to be slightly drier than that found in northern Idaho.

OTHER VEGETATION TYPES

This classification treats the vast majority of forested environments in northern Idaho. Communities where recurring disturbance is part of the natural environment—for example, avalanche chutes or flood plains—have not been classified but could be included in future work at the community-type level, as is being done with wetlands for the Northern Region, USDA Forest Service (Pierce 1986).

Forested Scree Communities (SCREE)

Slopes dominated by loose fragmented rock are termed talus, scree, or rock fans (debris). Although these excessively drained sites are often treeless in other locales, the high precipitation regime of northern Idaho is frequently sufficient for these sites to support trees, shrubs, and drought-tolerant herbs. Ecologically, these stands may approach a dynamic equilibrium with their perpetually shifting substrate.

The environment of these sites is spatially heterogeneous, owing to differential sorting of rock fragments, variation in the rate of debris movement, and subsurface drainage patterns. Scree sites are characterized by steep (>30 degrees), unstable slopes (hence frequent, natural interruption of normal successional patterns), usually with warm, dry exposures. These sites occur most abundantly along the slopes of deeply incised drainages. Forested scree slopes have widely spaced trees (low stockability and productivity), are difficult to regenerate, and have a shrub layer of variable density and composition. Occasionally the undergrowth may be forb-dominated, with half-shrub *Penstemon* spp. being a conspicuous component. Typically, these sites support tree species adapted to conditions of limited soil moisture; that is, *Pinus ponderosa*, *P. contorta*, and *Pseudotsuga menziesii*. *Thuja plicata*, *Abies lasiocarpa*, *A. grandis*, and even *Tsuga heterophylla* occur under the most favorable moisture conditions, where they are able to tap subsurface water.

We have followed the approach of Pfister and others (1977) and recognized a generalized forested scree condition (abbreviated SCREE) because of the high degree of intrasite and intersite variability and the dominant topoedaphic influence. SCREE is distinguished at the series level to prevent users from trying to identify these sites at an h.t. level. The hazards and limited opportunities associated with these sites preclude intensive management; only natural or low-impact uses such as for wildlife, watershed, and recreation are appropriate.

Flood Plain and Riparian Communities

Flood plains are formed on some of the shallow-gradient portions of major drainages of northern Idaho; these conditions are especially notable along the lower St. Joe and

Kootenai Rivers. Here, flood plains and riparian stringers are subject to fluctuations in stream actvity that periodically alter substrate depths and composition, and water table levels. Community analysis is often complicated by the added disturbance of livestock use. These recurring interruptions to successional processes pose unique challenges in applying the potential climax concept. Despite these perturbations, relatively stable plant communities can develop and are recognizable at the community-type level (Pierce 1986; Tuhey 1981).

Overstory dominants occur in varying proportions of *Populus* spp. (mostly *trichocarpa*), *Betula* spp., *Salix* spp., *Alnus* spp., and *Crataegus* spp., with various conifer species being weakly represented. The undergrowth is usually lush and patterned by small-scale topoedaphic effects.

Alnus sinuata Communities

Pure stands of *Alnus sinuata* and mosaics of *A. sinuata* with conifers and other shrub species occur throughout northern Idaho. Successional status of these communities varies from early pioneer secondary succession stages following site disturbance by wildfire, avalanche, or massive soil slumping, to long-lived midseral and climax communities on sites having high water tables, seasonally high soil moisture resulting from late-melting snowpacks, or old, healing talus slopes.

Alnus mosaics occur in all series but tend to be more extensive and a management problem in *Abies grandis*, *Abies lasiocarpa*, *Tsuga heterophylla*, and *Tsuga mertensiana* series. The density of the partially prostrate, springy stems impedes travel of both humans and livestock, generally restricting use of these stands to wildlife. The only tree species regularly associated with pure *Alnus* stands is *Picea engelmannii*, which seldom develops beyond the seedling or small sapling stage.

Shrub species associated with these communities are *Acer glabrum*, *Ribes lacustre*, *Salix* spp., *Sambucus* spp., *Sorbus* spp., and *Menziesia ferruginea*. Herbaceous species are usually shade tolerant and moisture requiring such as: *Asarum caudatum*, *Athyrium filix-femina*, *Circaea alpina*, *Clintonia uniflora*, *Dryopteris austriaca*, *Montia dordifolia*, *Montia sibirica*, *Pteridium aquilinum*, *Senecio triangularis*, *Trautvetteria caroliniensis*, *Valeriana sitchensis*, and *Veratrum viride*.

Soils developing under nearly pure *Alnus* stands tend to be moist to wet, relatively deep, and normally have a 12- to 24-inch deep (30- to 61-cm), dark colored, base-leached, diagnostic upper horizon (umbric epipedon), very high in organic carbon and low pH values (relatively poor nutrient source). Nevertheless, soil properties can vary widely under pure *A. sinuata*, including soils with light-colored diagnostic upper horizon(s) (ochric epipedons) and ones that are seasonally dry throughout the upper 60 inches (1.5 m). Efforts to link the presence of these communities to various site factors, including parent materials, have thus far not borne results.

In northern Idaho attempts to convert pure *A. sinuata* stands to coniferous forest have generally been failures. On drier sites an *A. sinuata*-conifer mosaic has responded favorably to low-acreage clearcuts and uneven-aged management. But wet sites have produced highly competitive pure stands of *Alnus* and other species. Shrub competition, and damage by pocket gopher and varying hares are major management considerations in all the *A. sinuata* community types. Research on the feasibility and effective techniques to convert these communities is needed before further conifer regeneration is attempted.

Small disjunct populations of *Alnus rubra* occur scattered throughout northern Idaho (Johnson 1968; Steele 1971). These are generally restricted to very moist, warm sites below 2,500 ft (760 m). These sites are often located on major slump zones and therefore indicate a potential for periodic disturbance.

Alnus sinuata/Montia cordifolia h.t. (ALSI/MOCO; Sitka alder/miner's lettuce)

Distribution—ALSI/MOCO is a relatively minor h.t. found throughout northern Idaho, occurring most frequently on the Selway Ranger District, Nez Perce NF, and the Lochsa and Powell Ranger Districts, Clearwater NF. It has been found at elevations ranging from 3,500 ft (1,070 m) to over 5,000 ft (1,520 m), on aspects generally northwest to east. Slopes vary from gentle to moderate. The h.t. of adjacent drier (upslope) positions is frequently ABGR/ASCA, THPL/ASCA, or TSHE/ASCA; where ALSI/MOCO occurs on sites with a high soil moisture status it grades to ABGR/SETR or THPL/ATFI on yet wetter sites.

Vegetation—*Alnus sinuata* forms a dense upper canopy, virtually the only shrub/tree present. Occasional *Picea engelmannii* seedlings establish, but appear to never develop beyond the sapling size class. Small islands of conifers do establish and grow exceptionally well inside some *Alnus* stands, but further investigation shows these are actually islands of different soil conditions in an otherwise homogeneous habitat.

Understory vegetation in many stands is limited to *Montia cordifolia* alone. Other species which occur in much reduced amounts are *Asarum caudatum*, *Circaea alpina*, *Montia sibirica*, *Senecio triangularis*, *Veratrum viride*, and the ferns *Athyrium filix-femina* and *Pteridium aquilinum*. Generally, the presence of four or five species, in addition to *A. sinuata* and *M. cordifolia*, is indicative of an ecotone to the previously mentioned "conifer-island" soil condition.

Soils—Parent materials vary from volcanic ash to highly weathered granites to glacial till of metasedimentary origin. Soils generally exceed 40 inches (1 m) in depth and often dry throughout the rooting zone by late July and August. Soil family classification is usually a Typic or Andic Cryumbrept or Andic Cryochrept. Textures tend to be coarse sands to sandy loams, and structure is usually single grain to weak granular. The pH varies from 4 to 5.5 and is generally 1.0 pH unit lower than that of adjacent conifer-occupied sites (see Other Studies section regarding successional status/genesis of these sites).

Productivity/Management—We know of no successful management attempt to establish conifers on these sites. Silvicultural treatments on *Alnus*-dominated sites should only be performed where relatively recent site occupancy by *Alnus* can be confirmed. The highly productive

"conifer-islands" intermixed with this type should receive immediate regeneration treatment following overstory removal. Among other problems within this h.t. are high population densities of pocket gophers and hares. ALSI/MOCO sites produce abundant browse and thermal and hiding cover for wildlife.

Other Studies—This h.t. has not been previously described. All communities wherein *A. sinuata* is virtually the sole upper canopy dominant have heretofore been considered secondary successional stages of conifer-dominated h.t.'s. However, the stands analyzed in the study indicate that *Alnus sinuata* has long been the canopy dominant, perhaps for a period of time sufficient to develop a soil horizonation different from adjacent conifer-dominated sites. At least two alternative hypotheses can be advanced to explain this *A. sinuata* site dominance: (1) Site properties (ostensibly those of the soil) are inherently unfavorable to conifer establishment; initial site differences are possibly accentuated by continued *A. sinuata* dominance. (2) Chance phenomena in stand development have resulted in *A. sinuata* site dominance which in turn has generated through autogenic processes site modification favoring the continued dominance of *A. sinuata*. We speculate, seeing no evidence to the contrary, that *A. sinuata* will continue to occupy these sites to the virtual exclusion of conifers and thus consider them examples of long-term stable or climax vegetation (recognized at h.t. level). Although research is needed, this also appears to be the situation on certain *Pteridium aquilinum*-dominated sites.

CHARACTERIZATION AND DISTRIBUTION OF HABITAT TYPES

Climate

Appendix E shows, via Walter (1973), diagrams arranged by series, climatic patterns representative of various habitat types. Most of the cited weather stations have long-term records. The habitat type indicated for each station is an estimation of the local climatic climax. Some caution should be exercised in applying climatic records to vegetation data; one must ascertain that the vegetation in the proximity of the station expresses the potential climatic climax and not an edaphic or topoedaphic condition. In rugged, mountainous terrain, particularly in the intermountain valleys where the great majority of weather stations are located, and the low-lying land may be blanketed with glacial drift, determination of climatic climax is not practicable.

Soils

Our soils data vary in completeness. Some researchers contributed much vegetation data but had not recorded information on soils; others had recorded characteristics of only the upper 4 to 8 inches (10 to 20 cm) of the mineral soil; whereas the authors described soil profiles to control depth or to an impermeable layer on every sample plot (totaling more than 600 plots). Preliminary results for characteristics of the upper horizon(s) and other important factors (for example, effective rooting depth) are presented in appendix D (for syntaxa with three or more samples) and as a paragraph following most habitat type descriptions.

Previous soil sampling strategies for the Northern Region and Intermountain Region have been designed to simply characterize the surface soil for each h.t. rather than investigate detailed soil-vegetation relationships. Our intention in acquiring complete profile descriptions is to build a data base for future soil-vegetation-site productivity research and to correlate our studies with those of Northern Region soil scientists. Based even on our limited data, some habitat types appear strongly controlled by edaphic or topoedaphic factors and express a narrow range in soil values; other h.t.'s are found on a wide range of soil conditions. The most salient associations between h.t.'s and soil conditions occur on sites with seasonally or permanently high water tables (THPL/OPHO, THPL/ATFI, ABLA/STAM, ABLA/CACA); these sites have less gravel (except THPL/OPHO), finer textures, higher pH, and deeper litter accumulations than upslope, well-drained sites. Neiman (1986) identified four soil physical characteristics that appear to be highly useful for differentiating between the extremely similar ABGR/CLUN, ABGR/ASCA, THPL/CLUN, THPL/ASCA, TSHE/CLUN, and TSHE/ASCA h.t.'s. His study indicates that data stratification into narrowly defined parent material groups within a restricted geographic area is a requisite to meaningful analysis.

The influence of parent material on vegetation patterns, which is so evident in Montana (east of the Continental Divide [Pfister and others 1977]) and northwestern Wyoming and adjacent Idaho (Steele and others 1983), is not manifested in obvious ways under the Inland Maritime climatic regime of northern Idaho. Of the commonly occurring parent material groups, the most strongly contrasted pair in terms of their influence on vegetation in Montana, calcareous versus noncalcareous, are rarely represented in northern Idaho owing to a lack of calcareous substrates (<1 percent of plots). Valley locations and loess-derived soils are underrepresented in the dataset because these lands are largely both privately held and deforested. Due to the extensive level of this study, insufficient representation within contrasting parent materials precludes demonstrating significant contrasts in terms of vegetation response.

The soil moisture regime and depletion rate studies of McMinn (1952) and Daubenmire (1968b) have demonstrated that these rates differ significantly and predictably among types, but these differences are not necessarily demonstrable by conventionally inventoried soil properties (for soil classification, USDA 1975). The often-advanced hypothesis that vegetation types (h.t.'s) are predictable from a standard set of soil characteristics was discredited in northern Idaho by the Daubenmires (1968). Even on a local scale (Priest River Experimental Forest), Daubenmire (1973) demonstrated poor correlation between habitat types and soils at even the Order level of soil classification. This result is not unexpected because (1) soil classification systems are not designed to reflect primarily those properties influencing vegetation development; (2) vegetation response to climatic fluctuation is relatively rapid, whereas development of equilibrium in soil properties requires a relatively long time; (3) many factors, of which soil characteristics are only one, influence vegetational

development, and through factor compensation species are able to grow on a wide range of substrates (soils); and (4) a rather coarse vegetation classification containing large within-type variation was used. Thus, one must exercise caution when attempting to "shortcut" inventories of either vegetative potentials or soils through a process of assumed correlations; relationships must be objectively and adequately tested and cautiously extrapolated. The results of Neiman (1986) indicate that with adequate data and proper stratification, certain of the physical soil characteristics can be correlated with identifiable vegetation patterns.

Vegetation

Species Occurrence

Appendix B is an interpretation, based primarily on field samples, of where (h.t. and phase) tree species occur. Appendix B provides a synopsis for selecting and managing tree species in accordance with their successional role in, and adaptation to, specific habitats.

For 113 "important" species, those with high constancy or indicator significance, appendix C lists the constancy and average coverage (for plots in which the species occurs) for each h.t. and phase. Insight into the classification structure can be gained through study of this table; it also serves as a summary of the composition of sample stands and a basis for evaluating a species' ecological amplitude and abundance in late successional stages.

Examples of questions that might be posed and answered using these appendixes are: What is the relative importance of *Pinus ponderosa* in the *Thuja plicata* series? Referencing appendix B opposite the THPL series under column 1, note that *P. ponderosa* is weakly represented as a seral or accidental species. What tree species occur within ABGR/ASCA-TABR h.t.? What are their successional roles? How abundant are they? Here again we could use appendix B to answer the first two parts. But appendix C is better suited to answering questions regarding abundance, recalling however that these are figures for mature to near climax communities. If you were provided planting stock of *Acer glabrum* and *Prunus virginiana* for big game habitat improvement, in what h.t.'s and phases would you plant? Scanning appendix C across all series for these species shows *A. glabrum* to have a broader amplitude than *P. virginiana*, occurring in TSHE, THPL, and even ABLA, as well as on the warmer ABGR and PSME series. *Prunus virginiana* is confined to warmer, drier portions of ABGR, as well as PSME and PIPO; nowhere is it an important species in later successional stages.

Timber Productivity

Timber productivity is one of the key management concerns for which data were accumulated during the study. Our data base for estimating productivity by habitat type is much reduced compared to that for characterizing the vegetational composition because (1) near-climax stands frequently have no suitable site trees; and (2) we have borrowed many plots from studies interested primarily in vegetation classification, in which they did not record associated productivity features.

All site trees were relatively free-growing, of dominant and codominant crown classes. We have expanded the number of trees sampled, from one per species per plot, as done in previous regional studies (Steele and others 1981, 1983; Pfister and others 1977), to three to five (or more) trees per species per plot to better represent the within stand variation. Preliminary indications from work in western Montana for four major seral species are that a one-tree sample will be within ± 9 to 10 site index units (50-year base) of the true mean 90 percent of the time; five tree samples will be within ± 3 to 5 site index units of the true mean 90 percent of the time (Fiedler 1983).

We adhered to the criteria of Pfister and others (1977) for recognizing suppressed trees by increment core analysis, rejecting those with 10 or more years of suppression. Preliminary onsite counting of tree rings, examination of their pattern, and tree height computation enabled us to recognize and delete from the data set those trees whose radial growth reflected a questionable or atypical height growth rate. Some sites with high incidence of root rot or Indian paint rot (*Echinodontium tinctorium*) required coring of 10 to 12 trees of one species to attain an acceptable three- to five-tree sample. For any mature stand the probability is high that all site trees have incurred some degree of growth reduction caused by insects, disease, or short-term climatic phenomena (drought years of late 1930's are readily detectable). Though such damage can be detected by ring width measurements (Carlson and McCaughey 1982) for determining the frequency and severity of past pest population eruptions, these measurements are not currently applicable for assessing the degree to which tree height or stand productivity has been reduced. It is also possible that some habitat types are more subject to higher incidences or greater degrees of growth reduction. We mention these factors as a cautionary note to uncritical acceptance or comparison of the timber productivity of various habitat types.

Each species requires a specific algorithm for computing its site index. Most site index computations require total age and height to utilize the curves; the age to breast height (4.5 ft [1.4 m]), which varies with stand history and h.t., must be estimated or measured. For species not having a specific site curve, a curve from a species hypothesized to have a similar growth curve is substituted. Table 2 summarizes the criteria used to determine total age and the source of site index curves; some of our curve selections differ from those employed in previous regional classifications for the reasons outlined below. See Steele and Cooper (1986) for a compilation of applicable site curves.

Pseudotsuga menziesii site indexes were determined using Monserud's (1984a) curves, which are derived from stem analysis of stands throughout our study area and based on breast-height age.

For *Picea engelmannii* we employed Clendenen's (1977) 50-year age base modifications of Alexander's (1967) curves. These curves are not very different from Brickell's (1970) and have the advantage of being based on breast-height age and have yield data associated with them (Alexander and others 1975). We also used Clendenen (1977) for *Abies lasiocarpa* and *Tsuga mertensiana*, reasoning that all three have similar ecological roles in subalpine ecosystems and may possess similar growth curve form.

Table 2—Criteria and sources for determining site index

Species	Estimated years to reach breast height	Source of site curve and area for which derived
ABLA	*[1]	Used *Picea engelmannii* curves
ABGR	*	Stage (1959); northern Idaho, eastern Washington
LAOC	5	Schmidt and others (1976); western Montana, northern Idaho
PIEN	*	Alexander (1967); Colorado and Wyoming
PIAL	*	Used *Picea engelmannii* curves
PICO	5	Brickell (1970); northern Idaho, eastern Washington, western Montana
PIMO	5	Haig (1932); northern Idaho
PIPO	10	Brickell (1970); northern Idaho, eastern Washington, western Montana
PSME	*	Monserud (1984); northern Idaho, northwestern Montana
THPL	8	Used *Tsuga heterophylla* curves
TSHE	8	Barnes (1962); western Oregon, Washington, Alaska, and British Columbia
TSME	*	Used *Picea engelmannii* curves

[1]* Indicates breast height age used to enter curves.

We used Barnes' (1962) curves derived for coastal *Tsuga heterophylla* for both inland populations of *T. heterophylla* and *Thuja plicata*, based on the similarity of their growth forms and ecological roles.

The site index data (50-year base age) and basal areas have been summarized by species within types and phases (appendix F).

We have computed an average site index whenever values exist for three or more stands; for five or more values a 90 percent confidence interval (CI) for estimating the true population mean was computed. The population sampled for site index (S.I.) is a species as it occurs on a given h.t. (or phase). An example for interpretation: average S.I. = 50, CI = ± 10 (90 percent), n = 15, means that if one were to take 15 S.I. readings (sample 15 stands for a given species and h.t.), then 90 percent of the time the true S.I. mean for that species on the specified h.t. will lie between 40 and 60. The CI narrows with both increased sample size and decreased variability.

For many of the same reasons that considerable vegetational variation occurs within a given h.t., so, too, do we expect variability in productivity estimates, within and between species, within types. Even though all species are related to a 50-year age base, the difference in estimates based on actual breast-height age versus adjusted total age means the species' S.I. values are not strictly comparable. On less productive h.t.'s the time to reach breast height may be as much as two to five times greater than that on more productive sites. The shortcomings outlined by Daubenmire (1961) in using anamorphic site index curves are still with us and cast a degree of doubt on using index values for comparative purposes; Monserud (1984b, 1985) is yet more critical of anamorphic curves and the whole site index concept, from outmoded curve construction techniques to erroneous assumptions made in predicting volume productivity.

Pfister and others (1977) have noted productivity differences between eastside and westside (of Continental Divide) stands for a given h.t. We recognize the desirability of regionally stratifying our site index data, but our data are presently insufficient for this approach. Preliminary indications are that h.t. productivities for the study area tend to be higher than for comparable types of contiguous areas to the south or east. The most appropriate, meaningful stratification could be made by individual forests or divisions thereof, drawing upon their inventory data.

Previous regional h.t. publications have presented net yield capabilities (in ft^3/acre/year [m^3/ha/year]) by h.t. as being more meaningful than S.I. as estimates of site productivity. Brickell (1970) states "yield capability, as used by Forest Survey, is defined as mean annual increment of growing stock attainable in fully stocked natural stands at the age of culmination of mean annual increment." We agree that yield capability is a more meaningful comparison, but only when some estimate of confidence can be placed on the values. The curves presented by Pfister and others (1977) for relating S.I. to yield capability by species have relatively low R^2 and unspecified standard error of estimate values. Given the relatively low or uncertain confidence to be placed in these curves, the fact that these curves do not apply to S.I. values greater than 80 (commonly exceeded in northern Idaho), and the misuse to which the values generated have been applied, we feel it is best to refrain from their presentation at this time; again this is an area for which individual National Forests (or other agencies) could profitably generate their own conversions. Research is sorely needed to develop the relationships between site variables, h.t., species site index, basal area stockability, and productivity.

Geographic and Zonal Distribution of Habitat Types

With changing environments, individual species occur in a predictable sequence; h.t.'s also exhibit predictable patterns in local areas. On a larger scale, the sequence of h.t's will vary through additions or deletions, but their relative positions will remain constant. For example, *Abies grandis* h.t.'s occur in warmer and drier environments than *A. lasiocarpa* h.t.'s, but in certain north Idaho localities the *Thuja plicata* series may occur between the two *Abies* series.

Schematic diagrams (figs. 48-52) depict the relative positions of h.t.'s and phases for several environmentally and floristically different areas of northern Idaho. The diagrams are not literally accurate due to the impossibility of depicting a three-dimensional landscape or multidimensional environment in two dimensions and therefore are not literally accurate. In an actual mountain slope transect near one of the localities depicted in figures 48-52, the number of h.t.'s might be reduced or, conversely, expanded to include h.t.'s typical of topoedaphic peculiarities not portrayed on these diagrams.

As outlined in individual descriptions, most h.t.'s are found within certain areas of northern Idaho; their quantitative occurrence by National Forest, as reflected in sample numbers, is presented in appendix A. Lack of sample plots of a specific h.t. or phase for a given area implies that it is of minor importance, but not necessarily entirely absent.

Figures 48-52—Schematic representation of key tree and undergrowth species encountered along an increasing elevational gradient (temperature decreasing, precipitation increasing, left to right). Horizontal bars indicate the approximate ecological amplitude of species along the gradient; crosshatching indicates where trees are climax species (designating series) or where the undergrowth species serve as indicators of a particular h.t. or phase (see narrative for details).

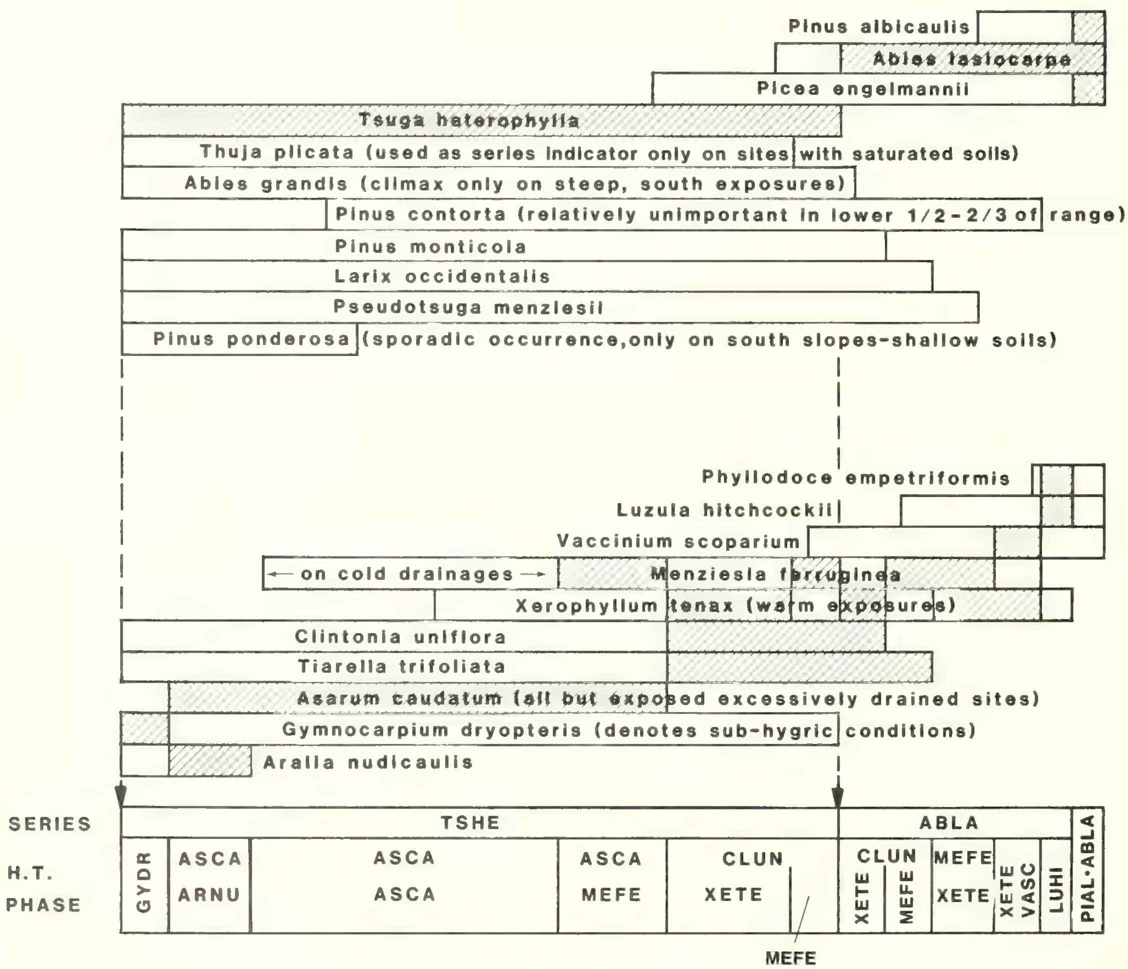


Figure 48—Schematic representation of the forest h.t. distribution with environmental gradients in the vicinity of Bonners Ferry, ID.

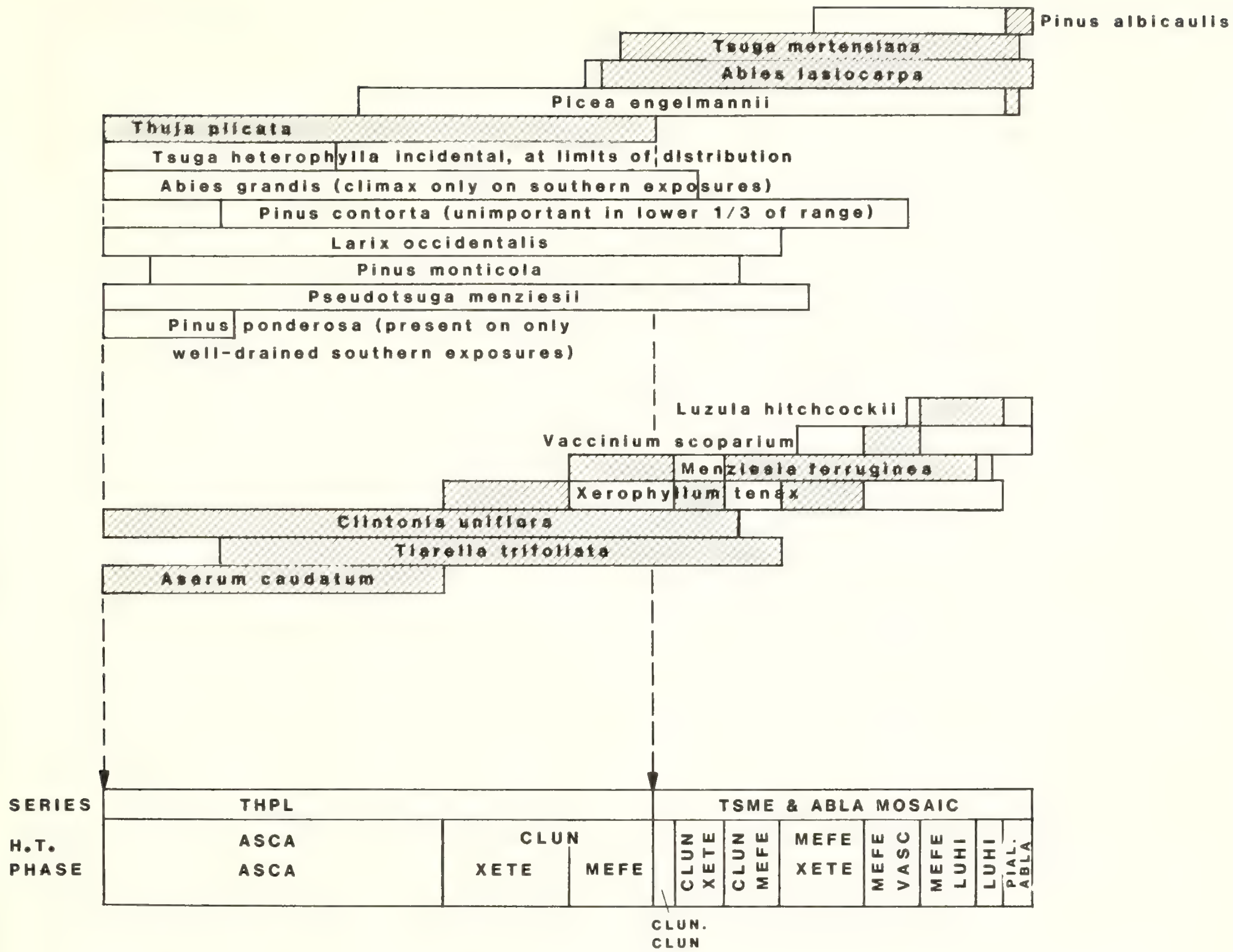


Figure 49—Schematic representation of forest h.t. distribution with environmental gradients in the vicinity of the Aquarius Research Natural Area, Clearwater NF.

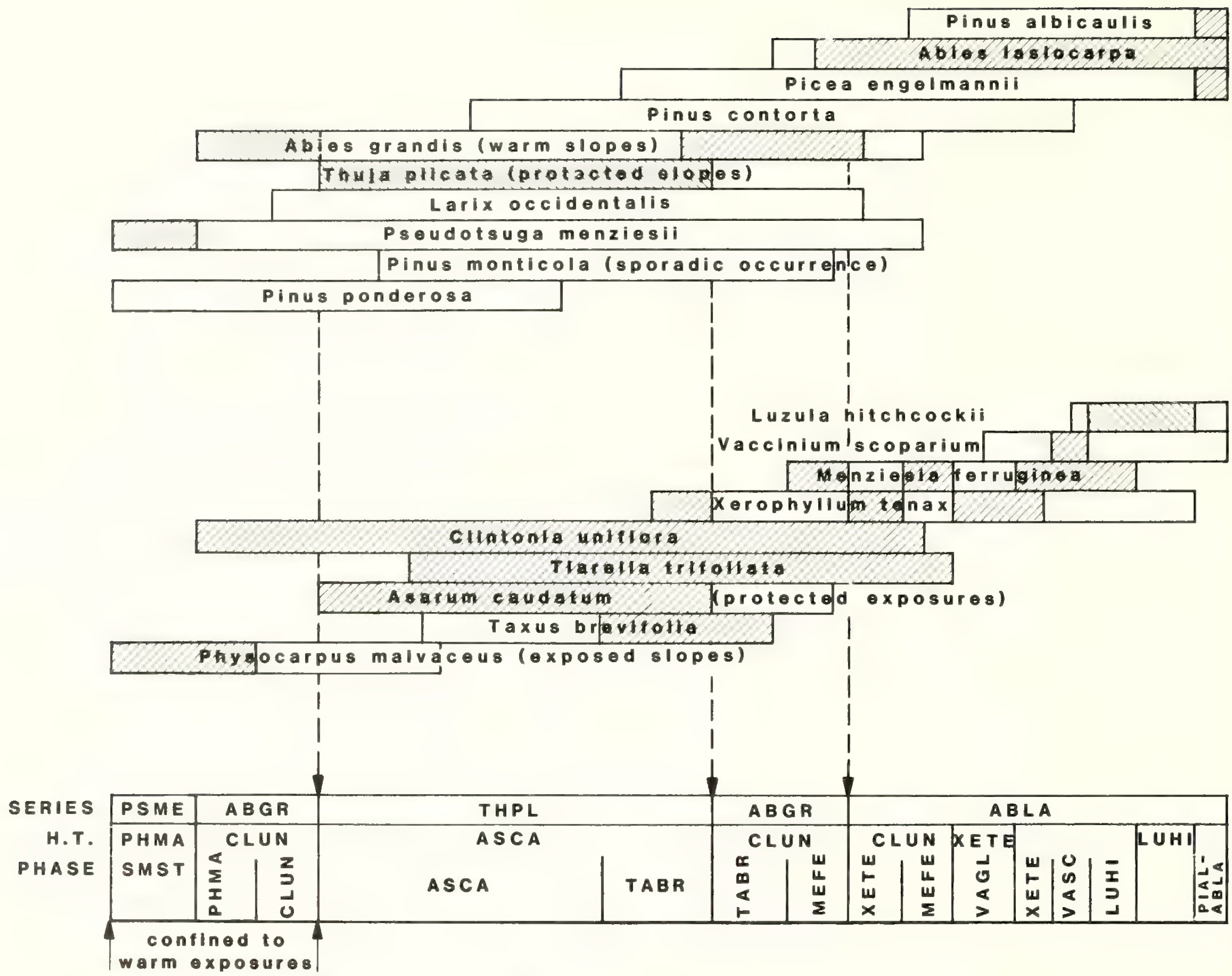


Figure 50—Schematic representation of forest h.t. distribution with environmental gradients in the vicinity of Fenn Ranger Station, Nez Perce NF.

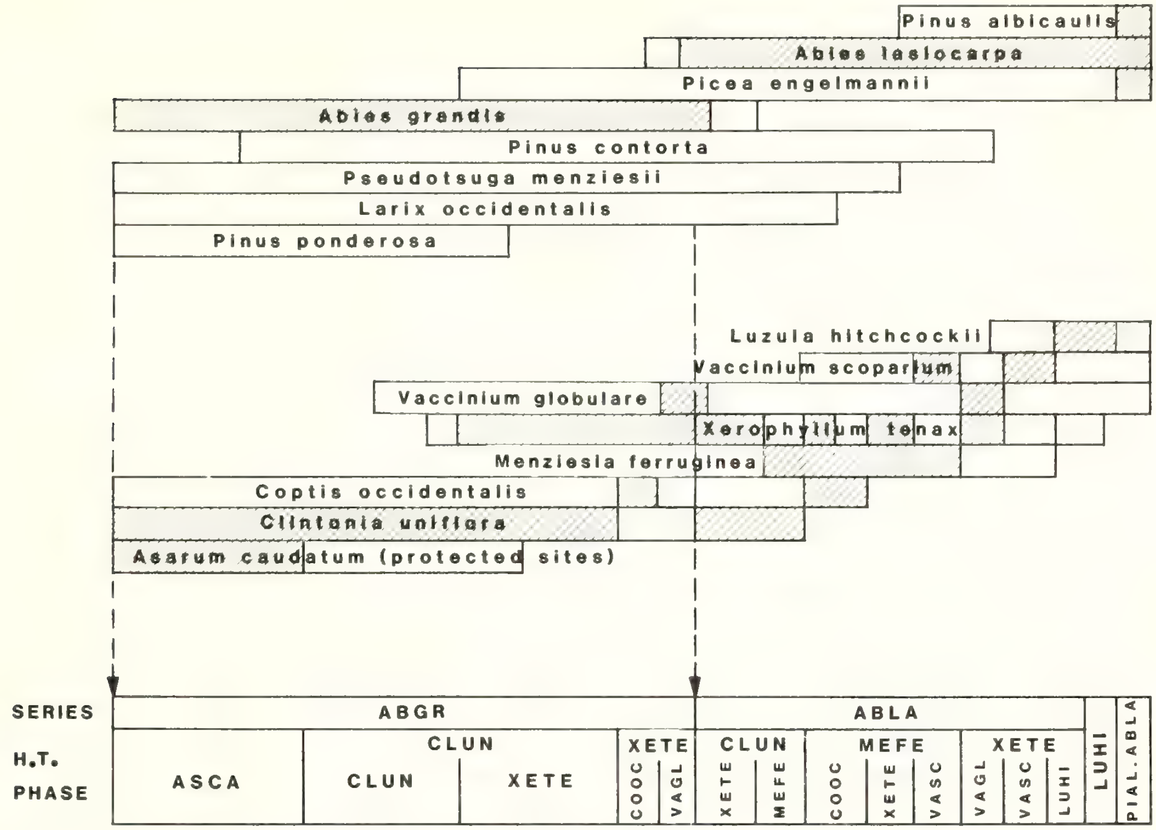


Figure 51—Schematic representation of forest h.t. distribution with environmental gradients in the vicinity of Elk City, ID.

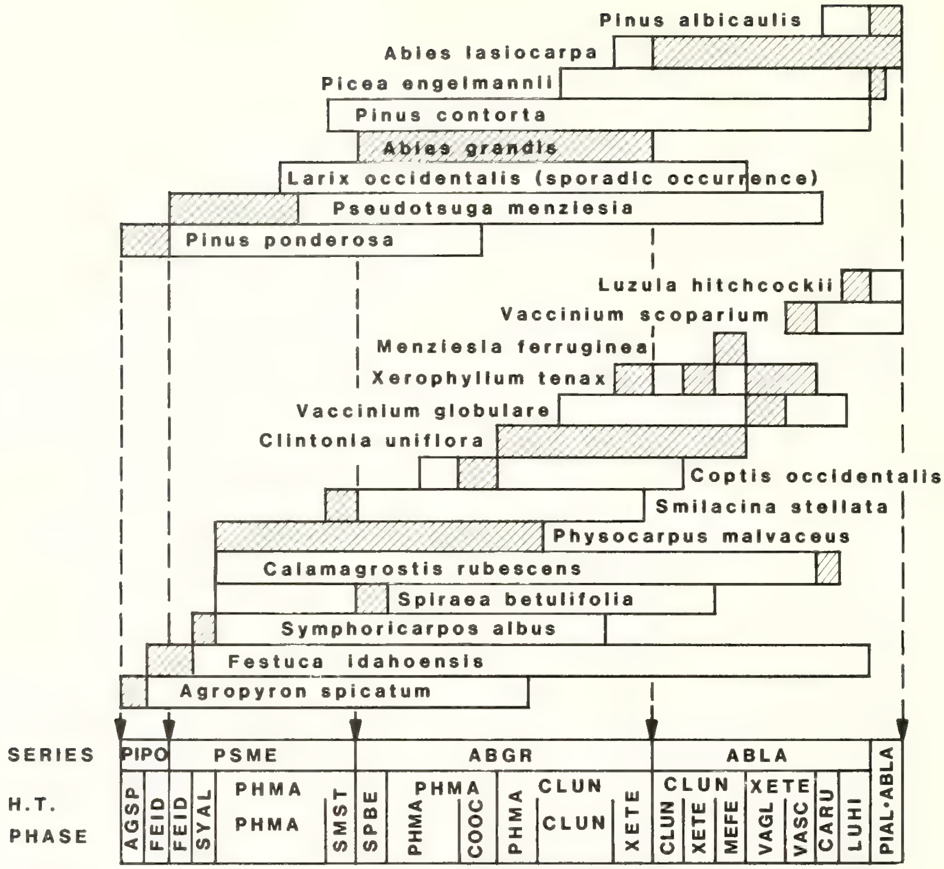


Figure 52—Schematic representation of forest h.t. distribution with environmental gradients in the vicinity of Seven Devils Mountains, Nez Perce NF.

Relationship to Previous Habitat Type Classifications in Idaho and Contiguous Areas

Our initial goal in producing this classification was to refine the pioneering work of Daubenmire and Daubenmire (1968) for northern Idaho. Since the Daubenmires' (1968) publication, classifications in areas contiguous to northern Idaho (Montana, Pfister and others 1977; central Idaho, Steele and others 1981) have served as successive approximations in understanding the vegetation distribution and ecology of this region. Our classification represents both a refinement of our predecessors' classifications and a tailoring of them to meet the ecological conditions peculiar to northern Idaho. Figure 53 illustrates how the variation encompassed in the series, h.t.'s, and phases of preceding classifications corresponds to our classification.

USE OF THE CLASSIFICATION

Our objectives in developing this classification have been to:

1. Provide a natural stratification of forested lands in terms of plant associations.
2. Correlate environmental site variables with plant associations, and, where appropriate, with individual species.
3. Provide a means of predicting both site quality and response following disturbance.
4. Provide baseline data set for the development of successional plant community classification for northern Idaho.

Use of Habitat Types

Habitat typing is most useful as a land stratification system—delineating land areas with approximately equivalent environments or biotic potential—a tool for: (1) reducing site-to-site variation within research and administrative studies; (2) cataloging field observations and intuitive evaluations; (3) modeling site response/secondary succession to various management decisions. In summary, habitat type classifications are basically information storage and retrieval systems, a foundation for basing predictions. Potential values of habitat types in resource management have been outlined by Layser (1974), Volland (1974), Daubenmire (1976), Pfister (1976), and Pfister and others (1977).

Some of the current and potential uses for habitat types include:

1. Communication: providing a common framework for site recognition and interdisciplinary activities.
2. Timber management: assessing site and species response to silvicultural prescriptions, species selection for planting, cutting, and regeneration, and assessing relative timber productivity.
3. Range and wildlife management: assessing relative forage and browse production for wild and domestic ungulates, and comparing potential wildlife habitat values.
4. Watershed management: estimating relative precipitation, evapotranspiration, and moisture-holding capacities, recognizing areas of heavy snowpack, high water tables, or high potential for surface erosion or mass wasting.
5. Recreation: assessing suitability for various types of recreational use, site impacts due to recreational use, and esthetic recovery rates following stand disturbances.
6. Forest protection: evaluating fuel buildup, fuel management and the natural role of fire (frequency and intensity of burns), assessing susceptibility to forest pests, diseases, and soil erosion.
7. Natural area preservation: ensuring that a complete environmental spectrum is represented in research natural areas.
8. Research: stratification tool for designing studies, analyzing results, modeling responses, and extrapolating study results to related sites. For instance, habitat type is a most important predictor variable in both the Prognosis and Regeneration Establishment Models.

Some management implications are discussed in the descriptions of the habitat types in this report. Appendix data can provide additional implications through interpretation by ecosystems-oriented specialists. Field personnel can also document personal observations to help expand our knowledge of vegetational responses on specific habitat types.

One caution, however, is that habitat types are **not** a panacea for all decision-making or site response interpretations. Habitat types **will** complement information on soils, recreation, hydrology, and wildlife, and will aid development of intensive land management.

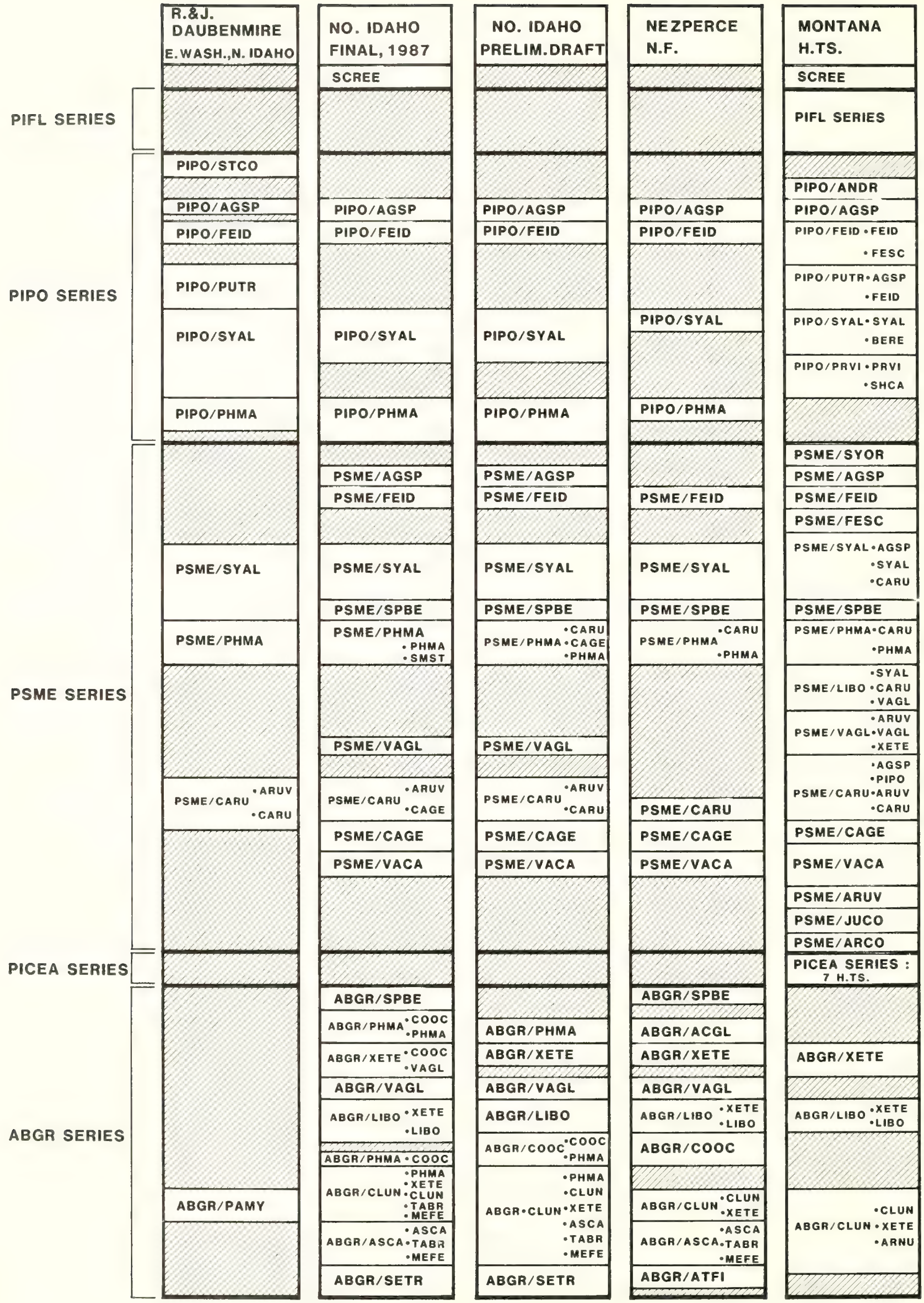


Figure 53—Correspondence of the second-approximation northern Idaho h.t. classification to existing classifications of the same and contiguous areas.

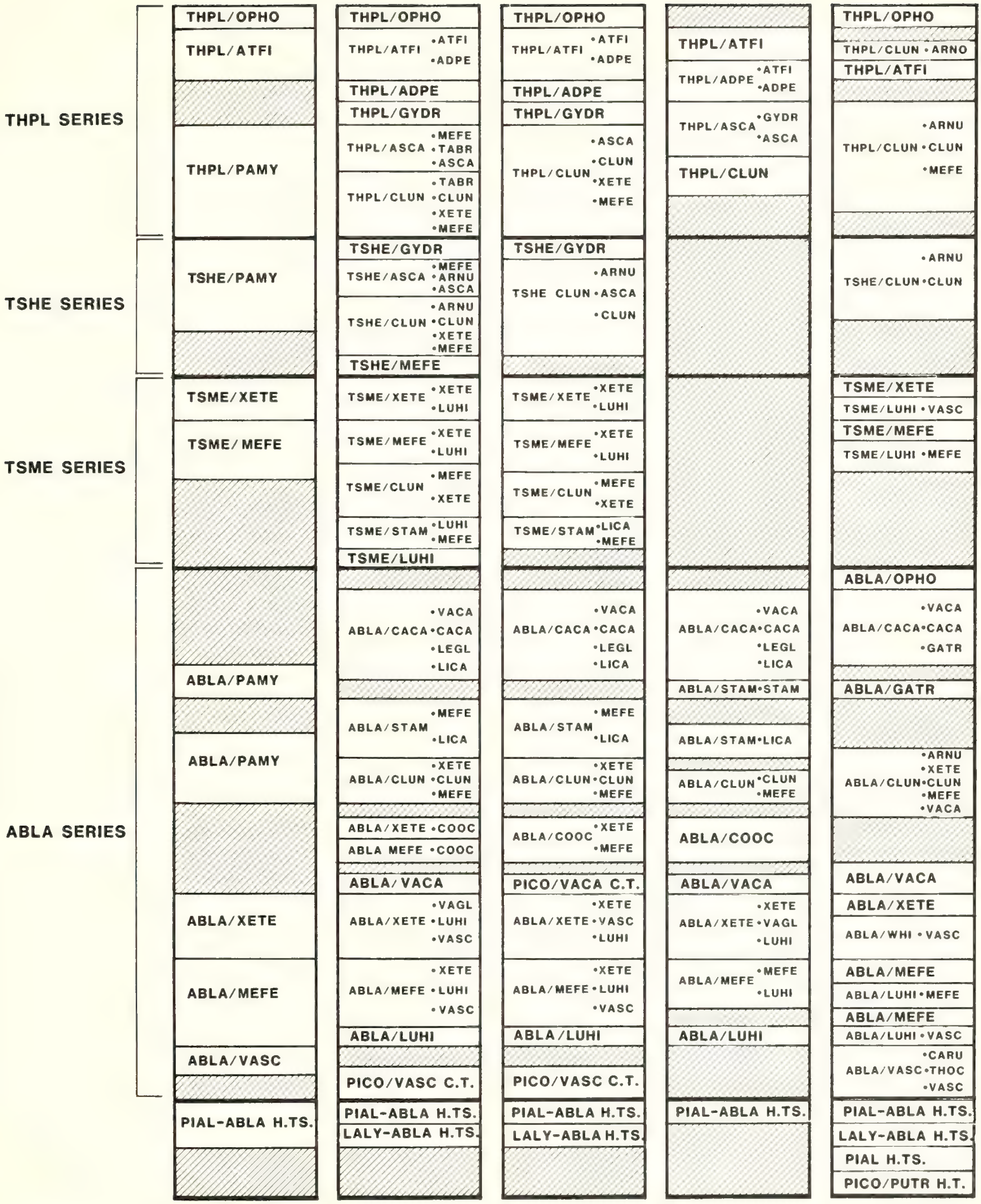


Figure 53 (Con.)

Mapping

Habitat type maps have become an important management tool in the Northern Region of the Forest Service (Deitschman 1973; Stage and Alley 1973; Daubenmire 1973). Maps provide a permanent record of habitat type distribution on the landscape and a basis for acreage estimates for land-use planning. Habitat type maps do **not** provide a substitute for maps of existing vegetation. Proper planning and silvicultural prescriptions require knowledge of both the **present** and **potential** vegetation.

Maps may be created at different scales and degrees of accuracy, depending on one's objectives. Wherever it is even remotely practical, all habitat type mapping should be done at the phase level. As our classification is hierarchical in nature, agglomerative procedures can be used to create more inclusive mapping units for use at project, district, forest, or regional level. For research studies and project planning, maps should be accurate and detailed; each **phase** of a habitat type should be delineated. The map scale should range from 4 to 8 inches per mile (10 to 20 cm per 1.6 km). At a broader level of planning (district or forest), map scale may decrease (loss of detail) and all necessary information included at the habitat type level. Map scale in this case ranges from 0.5 to 4 inches per mile (0.8 to 6 cm per 1.0 km). Still broader levels of mapping may be desirable for regional needs (zone, state, or region). These may employ scales of 0.25 to 0.5 inch per mile (0.4 to 0.8 cm per 1.0 km), and may depict only habitat type groups or dominant tree series. These should be synthesized from large-scale habitat type maps whenever possible.

At scales of 4 to 8 inches per mile (10 to 20 cm per 1.6 km), the habitat types and phases should be the mapping units, accepting inclusions (up to 15 percent) of other types too restricted in acreage to separate. In complex terrain and at smaller scales special mapping units may be developed. Such mapping unit complexes must be defined for each area being mapped, as in most cases they will be unique to that area and that mapping project's objectives. The amount and relative positions of habitat types and phases within a complex must be documented as management interpretations of a mapping unit are tied to these taxonomic units—series, habitat type, and phase. The amount and location of field reconnaissance should also be specified on the map or in a report for users of the map.

Selection of a mapping approach and scale should be based on the following: (1) anticipated use of the map, (2) accuracy level required, (3) availability of trained personnel, and (4) amount of time and resources available to achieve the specified accuracy level. The map, like the habitat type classification itself, is only an approximation based on the experience and judgment of personnel doing the interpretations. Maps should be considered dynamic tools, undergoing updating and correcting, changing in a direction of ever-increasing accuracy with use.

Grouping

The classification system in this guide was developed to be both natural and hierarchical. Because of this it can be used at various levels of differentiation for many purposes. We recommend collecting and recording of field data (vegetation or stand inventories) always be detailed enough for determination of habitat type and phase. A standard format such as the checklist/field form in appendix G is suggested. Data collected at this level of resolution enhance their current and future value and make possible more specific, detailed applications to research and resource management.

In a given area, a reduced percentage of the regionally recognized forest habitat types and phases will occur. Some h.t.'s will be so minor in extent that once their presence is documented they may not enter into broad-scale forest management planning. This leaves relatively few habitat types to be identified and mapped. After identification and mapping to phase level, regrouping into similar categories can facilitate resource planning at various levels. Table 3 is a suggested (Ferguson 1985) grouping of habitat types and phases on the basis of moisture and temperature relative to regeneration success and stocking probabilities. This is only one of many permutations that can be delineated based on ecological characteristics of h.t.'s. For example, in table 3 *Armillaria mellea* is a potential problem on disturbed sites in groups 4 through 14 (McDonald 1983). Alternatively, degrees of soil moisture could be recognized, aggregating, for instance, certain h.t.'s of groups 9, 13, 15, 16 of table 3 into a group representing saturated soil conditions

Table 3—Suggested grouping (Ferguson 1985) of habitat types and phases having similar moisture and temperature characteristics regarding regeneration success/stocking probabilities (see narrative, p. 96)

Group number	Members of group by habitat type
1	PSME/VACA; PSME/VAGL; PSME/LIBO
2	PSME/AGSP; PSME/FEID; PSME/FESC; PSME/CARU; PSME/CAGE
3	PSME/SYAL; PSME/SPBE; PSME/ARUV; PSME/ARCO; PSME/SYOR; PSME/BERE
4	PSME/PHMA; PSME/ACGL
5	ABGR/CLUN-XETE; ABGR/LIBO
6	ABGR/COOC; ABGR/XETE; ABGR/VAGL; ABGR/VACA
7	ABGR/CLUN-(CLUN, ARNU, PHMA phases)
8	ABGR/SPBE; ABGR/PHMA; ABGR/PHMA-COOC; ABGR/ASCA; ABGR/ACGL
9	THPL/CLUN-(CLUN, ARNU, MEFE, TABR phases); THPL/ASCA; THPL/ATFI; THPL/OPHO; ABGR/SETR
10	TSHE/CLUN-(CLUN, ARNU, MEFE phases); TSHE/ASCA; TSHE/MEFE
11	ABLA/VACA; ABLA/VAGL-VASC; ABLA/VASC-(CARU, VASC, THOC phases)
12	ABLA/LIBO-(LIBO, XETE, VASC phases); ABLA/XETE-VAGL, VASC phases)
13	ABLA/CLUN-(CLUN, ARNU, VACA, XETE, MEFE phases); ABLA/GATR
14	ABLA/MEFE; TSME/STAM; TSME/MEFE; TSME/CLUN; TSME/XETE; ABLA/ALSI
15	ABLA/ACGL; ABLA/SPBE; ABLA/CARU; ABLA/CAGE;-(CAGE, PSME phases)
16	ABLA/STAM; ABLA/CACA-(CACA, GATR phases); ABLA/LUHI

Where implications for management are similar, it may be desirable to consider an entire tree series, such as the *Pseudotsuga menziesii* or *Abies grandis* series, as one group. Recording at the phase level allows one to collapse similar groups, whereas if phases are not recorded, later splits or regroupings of the data will be impossible. Any document using habitat types and/or phases which have been grouped should include a complete description of the relative amounts of each habitat type and phase contained therein. An explanation of why the particular grouping was created is also an invaluable aid to map interpretation.

REFERENCES

Alexander, R. R. Site indexes for lodgepole pine, with corrections for stand density: instructions for field use. Research Paper RM-24. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1967. 7 p.

Alexander, R. R. Partial cutting in old-growth spruce-fir. Research Paper RM-110. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1973. 16 p.

Anderson, H. E. Sundance fire: an analysis of fire phenomena. Research Paper INT-56. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1968. 37 p.

Antos, J. A.; Habeck, J. R. Successional development in *Abies grandis* (Dougl.) Forbes forests in the Swan Valley, western Montana. Northwest Science. 55(1): 26-39; 1981.

Antos, J. A.; Shearer, R. C. Vegetation development on disturbed grand fir sites, Swan Valley, northwestern Montana. Research Paper INT-251. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 26 p.

Arno, S. F. Interpreting the timberline; an aid to help park naturalists to acquaint visitors with the subalpine-alpine ecotone of western North America. Missoula, MT: University of Montana; 1966. 206 p. M.S. thesis.

Arno, S. F. The historical role of fire on the Bitterroot National Forest. Research Paper INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 29 p.

Arno, S. F. Forest regions of Montana. Research Paper INT-218. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 39 p.

Arno, S. F. Forest fire history in the Northern Rockies. Journal of Forestry. 78(8): 460-465; 1980.

Arno, S. F.; Davis, D. H. Fire history of western redcedar/hemlock forests in northern Idaho. In: Stokes, M. A.; Dieterich, J. H., tech. coords. Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. General Technical Report RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980: 21-26.

Arno, S. F.; Habeck, J. R. Ecology of alpine larch (*Larix lyallii* Parl.) in the Pacific Northwest. Ecological Monographs. 42: 417-450; 1972.

Arno, S. F.; Hammerly, R. P. Timberline, mountain and arctic forest frontiers. Seattle, WA: The Mountaineers; 1984. 304 p.

Arno, S. F.; Petersen, T. D. Variation in estimates of fire intervals: a closer look at fire history on the Bitterroot National Forest. Research Paper INT-301. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 8 p.

Arno, S. F.; Simmerman, D. G.; Keane, R. E. Forest succession on four habitat types in western Montana. General Technical Report INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 74 p.

Arnold, J. F. Descriptions of sections and subsections of that portion of the Northern Rocky Mountain physiographic province containing the Idaho Batholith. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Region; 1975. 342 p.

Bailey, A. W. Forest associations and secondary plant succession in the southern Oregon Coast Range. Corvallis, OR: Oregon State University; 1966. 164 p. Ph.D. dissertation.

Barnes, G. H. Yield of even-aged stands of western hemlock. Technical Bulletin 1273. Washington, DC: U.S. Department of Agriculture, Forest Service; 1962. 52 p.

Barrett, J. W. Silviculture of ponderosa pine in the Pacific Northwest: the state of our knowledge. General Technical Report PNW-97. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 106 p.

Barrett, S. W. Fire's influence on ecosystems of the Clearwater National Forest: Cook Mountain fire history inventory. Orofino, ID: U.S. Department of Agriculture, Forest Service, Clearwater National Forest, Fire Management; 1982. 42 p. plus appendixes. [Unpublished].

Barrett, S. W.; Arno, S. F. Indian fires as an ecological influence in the Northern Rockies. Journal of Forestry. 80(10): 647-651; 1982.

Barrows, J. S. Forest fires in the Northern Rocky Mountains. Paper 29. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station; 1952. 103 p.

Basile, J. V.; Jensen, C. E. Grazing potential on lodgepole pine clearcuts in Montana. Research Paper INT-98. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1971. 11 p.

Bell, M. A. M. The dry subzone of the interior western hemlock zone. Krajina, V. J., ed. Ecology of western North America. Vancouver, BC: University of British Columbia; 1965: 42-64. Vol. 1.

Billings, W. D. Vegetation pattern near alpine timberline as affected by fire-snowdrift interactions. Vegetatio. 19: 192-207; 1969.

Boyd, R. J. Some case histories of natural regeneration in the western white pine type. Research Paper INT-63. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1969. 24 p.

Boyd, R. J.; Deitschman, G. H. Site preparation aids natural regeneration in western larch-Engelmann spruce strip clearcuttings. Research Paper INT-64. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1969. 10 p.

Bray, J. R.; Curtis, J. T. An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs. 27: 325-349; 1957.

Brayshaw, T. C. The dry forest of southern British Columbia. Part II. Ecotypes and biogeocoenotic units. In: Krajina, V. J., ed. Ecology of western North America. Vancouver, BC: University of British Columbia; 1965: 65-75. Vol. 1.

Brickell, J. E. Equations and computer subroutines for estimating site quality of eight Rocky Mountain species. Research Paper INT-75. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1970. 35 p.

Brooke, R. C. The subalpine mountain hemlock zone. Part II. Ecotypes and biogeocoenotic units. In: Krajina, V. J., ed. Ecology of western North America. Vancouver, BC: University of British Columbia; 1965: 79-101. Vol. 2.

Carlson, C. E.; McCaughey, W. W. Indexing western spruce budworm activity through radial increment analysis. Research Paper INT-291. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 10 p.

Cattelino, P. J.; Noble, I. R.; Slayter, R. O.; Kessel, S. R. Predicting the multiple pathways of plant succession. Environmental Management. 3(1): 41-50; 1979.

Cholewa, A. F.; Johnson, F. D. Secondary succession in the *Pseudotsuga menziesii/Physocarpus malvaceus* association. Northwest Science. 57(4): 273-282; 1983.

Ciesla, W. M.; Furniss, M. Idaho's haunted forest. American Forests. 81(8): 32-35; 1975.

Clendenen, C. W. Base-age conversion and site index equations for Engelmann spruce stands in the Central and Southern Rocky Mountains. Research Note INT-223. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 6 p.

Cole, D. N. Assessing and monitoring backcountry trail conditions. Research Paper INT-303. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 10 p.

Cooper, S. V. Forest habitat types of northwestern Wyoming and contiguous portions of Montana and Idaho. Pullman, WA: Washington State University; 1975. 190 p. Ph.D. dissertation.

Cooper, S. V.; Pfister, R. D. Ecology of Douglas-fir and grand fir in the Interior West. In: Baumgartner, D. M.; Mitchell, R. Silvicultural management strategies for pests of the interior Douglas-fir and grand fir forest types: Proceedings; 1984 February 14-16; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension Service; 1984: 11-23.

Cottam, G.; McIntosh, R. P. [Reply to Daubenmire 1966.] Science 152: 546-574; 1966.

Crawford, R. C. Pacific yew community ecology in north-central Idaho with implications to forest land management. Moscow, ID: University of Idaho; 1983. 109 p. Ph.D. dissertation.

Crawford, R. C.; Johnson, F. D. Pacific yew dominance in tall forests: a classification dilemma. Canadian Journal of Botany. 63: 592-601; 1984.

Currie, P. O.; Edminster, C. D.; Knott, F. W. Effect of cattle grazing on ponderosa pine regeneration in central Colorado. Research Paper RM-201. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1978. 7 p.

Daubenmire, R. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs. 22: 301-330; 1952.

Daubenmire, R. Climate as a determinant of vegetation distribution in eastern Washington and northern Idaho. Ecological Monographs. 26: 131-154; 1956.

Daubenmire, R. A canopy-coverage method of vegetational analysis. Northwest Science. 33: 131-154; 1959.

Daubenmire, R. Vegetative indicators of rate of height growth in ponderosa pine. Forest Science. 7: 24-34; 1961.

Daubenmire, R. Vegetation: identification of typal communities. Science. 151: 291-298; 1966.

Daubenmire, R. Plant communities, a textbook of plant synecology. New York: Harper-Row; 1968a. 300 p.

Daubenmire, R. Soil moisture in relation to vegetation distribution in the mountains of northern Idaho. Ecology. 49: 431-438; 1968b.

Daubenmire, R. Steppe vegetation of Washington. Technical Bulletin 62. Pullman, WA: Washington Agricultural Experiment Station; 1970. 131 p.

Daubenmire, R. A comparison of approaches to the mapping of forest land for intensive management. Forestry Chronicle. 49(2): 87-91; 1973.

Daubenmire, R. The use of vegetation in assessing the productivity of forest lands. Botanical Review. 42(2): 115-143; 1976.

Daubenmire, R. Mountain topography and vegetation patterns. Northwest Science. 54(2): 146-152; 1980.

Daubenmire, R. Subalpine parks associated with snow transfer in the mountains of northern Idaho and eastern Washington. Northwest Science. 55(2): 124-135; 1981.

Daubenmire, R.; Daubenmire, J. B. Forest vegetation of eastern Washington and northern Idaho. Technical Bulletin 60. Pullman, WA: Washington Agricultural Experiment Station; 1968. 104 p.

Davis, K. M.; Clayton, B. D.; Fischer, W. C. Fire ecology of Lolo National Forest habitat types. General Technical Report INT-79. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 77 p.

Deitschman, G. H. Mapping of habitat types throughout a National Forest. General Technical Report INT-11. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 14 p.

Despain, D. G. Vegetation of the Big Horn Mountains, Wyoming, in relation to substrate and climate. Ecological Monographs. 43: 329-355; 1973.

Despain, D. G. Nonpyrogenous climax lodgepole pine communities in Yellowstone National Park. Ecology. 64: 231-234; 1983.

Edwards, R. Y.; Ritcey, R. W. Foods of caribou in Wells Gray Park, British Columbia. Canadian Field-Naturalist. 74: 3-7; 1960.

Edwards, R. Y.; Soos, J.; Ritcey, R. W. Quantitative observations on epidendric lichens used as food by caribou. Ecology. 41(3): 425-431; 1960.

Ferguson, D. E. [Personal communication]. 1985. Moscow, ID: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Ferguson, D. E.; Adams, D. L. Response of advance grand fir regeneration to overstory removal in northern Idaho. Forest Science. 26(4): 537-545; 1980.

Ferguson, D. E.; Stage, A. R.; Boyd, R. J. Predicting regeneration in the grand fir-cedar-hemlock ecosystem of the Northern Rocky Mountains. Forest Science Monograph 26. Washington, DC: Society of American Foresters; 1986. 41 p.

Fiedler, C. Analysis of regeneration in the subalpine fir zone of western Montana. 1980. Manuscript on file at: U.S. Department of Agriculture, Forest Service, Forestry Sciences Laboratory, Bozeman, MT. 64 p.

Fiedler, C. E. Regeneration of clearcuts within four habitat types in western Montana. In: Baumgartner, D. M., ed. Site preparation and fuels management on steep terrain: proceedings of a symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension; 1982: 139-147.

Fiedler, C. [Personal communication]. 1983. Missoula, MT: University of Montana, School of Forestry.

Foiles, M. W.; Curtis, J. D. Regeneration of ponderosa pine in the Northern Rocky Mountain-Intermountain region. Research Paper INT-145. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 44 p.

Ford-Robertson, F. C., ed. Terminology of forest science, technology practice, and products. Multilingual Forest Terminology Series 1. Washington, DC: Society of American Foresters; 1971. 349 p.

Franklin, J. F.; Waring, R. H. Distinctive features of the northwestern coniferous forest: development, structure, and function. In: Waring, R. H., ed. Proceedings of the 40th annual biology colloquium. Corvallis, OR: Oregon State University Press; 1980: 59-85.

Frederick, D. J.; Partridge, A. D. Indicators of decay in the grand fir/white fir complex in central Idaho. Northwest Science. 51: 282-292; 1977.

Graham, R. T. Influence of tree and site factors on western redcedar's response to release: a modeling analysis. Research Paper INT-296. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 19 p.

Habeck, J. R. Mountain hemlock communities in western Montana. Northwest Science. 41: 169-177; 1967.

Habeck, J. R. Forest succession in the Glacier Park cedar-hemlock forests. Ecology. 49: 872-880; 1968.

Habeck, J. R. A study of climax western redcedar (*Thuja plicata* Donn.) forest communities in the Selway-Bitterroot Wilderness, Idaho. Northwest Science. 52(1): 67-76; 1978.

Habeck, J. R.; Mutch, R. W. Fire-dependent forests in the Northern Rocky Mountains. Quaternary Research. 3: 408-424; 1973.

Haig, I. T. Second-growth yield, stand, and volume tables for the western white pine type. Technical Bulletin 323. Washington, DC: U.S. Department of Agriculture; 1932. 67 p.

Haig, I. T.; Davis, K. P.; Weidman, R. H. Natural regeneration in the western white pine type. Technical Bulletin 767. Washington, DC: U.S. Department of Agriculture; 1941. 99 p.

Hall, F. C. Plant communities of the Blue Mountains in eastern Oregon and southwestern Washington. R-6 Area Guide 3-1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1973. 62 p.

Hall, F. C. Ecology of natural underburning in the Blue Mountains of Oregon. R6-ECOL-79-001. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1977. 11 p.

Hall, F. C. Application of a classification system based on plant community types (associations) with special reference to wildlife, range, and timber management. In: The scientific and technical basis for land classification: a joint technical session; 1980 October 7; Spokane, WA. Washington, DC: Society of American Foresters; 1980: 11-17.

Hanson, H. C. Dictionary of ecology. New York: Philosophical Library, Inc.; 1962. 382 p.

Harrington, M. G.; Kelsey, R. G. Influence of some environmental factors on initial establishment and growth of ponderosa pine seedlings. Research Paper INT-230. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 26 p.

Hemstrom, M. A.; Emmingham, W. H.; Halverson, N. M.; Logan, S. E.; Topik, C. Plant association and management guide for the Pacific silver fir zone, Mt. Hood and Willamette National Forests. R6-Ecol. 100-1982a. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1982. 104 p.

Henderson, J. A.; Mauk, R. L.; Anderson, D. L.; Ketchie, R.; Lawton, P.; Simon, S.; Sperger, R. H.; Young, R. W.; Youngblood, A. Preliminary forest habitat types of northwestern Utah and adjacent Idaho. Logan, UT: Utah State University, Department of Forestry and Outdoor Recreation; 1976. 99 p.

Henderson, J. A.; Peter, D. A. Plant associations and habitat types of the White River Ranger District, Mt. Baker-Snoqualmie National Forest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1981. 58 p. [Preliminary.]

Heuser, C. J. Late-Pleistocene coniferous forests of the Northern Rocky Mountains. In: Taber, R. D., ed. Coniferous forests of the Northern Rocky Mountains. Missoula, MT: University of Montana Foundation; 1969: 1-23.

Hitchcock, C. L.; Cronquist, A. Flora of the Pacific Northwest. Seattle, WA: University of Washington Press; 1973. 730 p.

Hoffman, G. R.; Alexander, R. R. Forest vegetation of the Bighorn Mountains, Wyoming: a habitat type classification. Research Paper RM-170. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1976. 38 p.

Hoffman, G. R.; Alexander, R. R. Forest vegetation of the Routt National Forest in northwestern Colorado: a habitat type classification. Research Paper RM-221. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980. 41 p.

Illingsworth, K.; Arlidge, J. W. C. Interim report on some forest site types in lodgepole pine and spruce-alpine fir stands. Research Note 35. Victoria, BC: British Columbia Forest Service; 1960. 44 p.

Johnson, F. D. Disjunct populations of red alder in Idaho. In: Trappe, J. M.; Franklin, J. F.; Tarrant, R. E.; Hansen, G. E., eds. Biology of alder: Symposium proceedings, Northwest Scientific Association 40th annual meeting; [dates unknown]; Pullman, WA. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1968: 1-8.

Kessell, S. R.; Fischer, W. C. Predicting post-fire plant succession for fire management planning. General Technical Report INT-94. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 19 p.

Kingery, J. [Personal communication]. 1983. Moscow, ID: University of Idaho, School of Forestry, Wildlife and Range Sciences.

Kosco, B. H.; Bartolome, J. W. Effects of cattle and deer use on regenerating mixed conifer clearcuts. Journal of Range Management. 36(2): 265-268; 1983.

Lanner, R. M. Avian seed dispersal as a factor in the ecology and evolution of limber and whitebark pines. Sixth North American forest biology workshop; 1980 August 11. Edmonton, AB: University of Alberta; 1980. 48 p. Invited paper.

Laurson, S. Predicting shrub community composition and structure following management disturbance in forest ecosystems of the Intermountain West. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1984. 261 p. Ph.D. dissertation.

Layser, E. F. Vegetation classification: its application to forestry in the Northern Rocky Mountains. Journal of Forestry. 72: 354-357; 1974.

Layser, E. F. Flora of Pend Oreille County, Washington. Pullman, WA: Washington State University, Cooperative Extension; 1980. 146 p.

Lillybridge, J. R.; Williams, C. K. Forested plant associations of the Colville National Forest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Ecology Program; 1984. 154 p. Review draft.

Little, E. L., Jr. Atlas of United States trees. Vol. 1. Conifers and important hardwoods. Miscellaneous Publication No. 1146. Washington, DC: U.S. Department of Agriculture; 1971. Not paged.

Löve, D. Subarctic and subalpine; where and what. Arctic and Alpine Research. 2: 63-73; 1970.

McCaughey, W. W.; Schmidt, W. C. Understory tree release following harvest cutting in spruce-fir forests in the Intermountain West. Research Paper INT-285. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 19 p.

McCune, B.; Allen, T. F. H. Will similar forests develop on similar sites? Canadian Journal of Botany. 63: 367-376; 1985.

McDonald, G. I. [Personal communication]. 1983. Moscow, ID: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

McLean, A. Plant communities of the Similkameen Valley, British Columbia, and their relationships to soils. Ecological Monographs. 40: 403-424; 1970.

McLean, A.; Lord, T. M.; Green, A. J. Utilization of the major plant communities in the Similkameen Valley, British Columbia. Journal of Range Management. 24: 346-351; 1971.

McMinn, R. G. The role of soil drought in the distribution of vegetation in the Northern Rocky Mountains. Ecology. 33: 1-15; 1952.

Mahoney, R. L. The effect of shade on western redcedar seedlings. Moscow, ID: University of Idaho; 1981. 79 p. Ph.D. dissertation.

Mauk, R. L.; Henderson, J. A. 1984. Coniferous forest habitat types of northern Utah and adjacent Idaho. General Technical Report INT-170. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 89 p.

Mehringer, P. J., Jr. Late-quaternary pollen records from the interior Pacific Northwest and northern Great Basin of the United States. In: Pollen records of late-quaternary North American sediments. Houston, TX: American Association of Straitigraphic Palynologists [AASP] Foundation; 1985: 167-189.

Minore, D. Comparative autecological characteristics of northwestern tree species—a literature review. General Technical Report PNW-87. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 72 p.

Minore, D. Western redcedar—a literature review. General Technical Report PNW-150. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1983. 70 p.

Moeur, M. COVER: a user's guide to the CANOPY and SHRUB extension of the Stand Prognosis Model. General Technical Report INT-190. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 49 p.

Moir, W. H. The lodgepole pine zone in Colorado. American Midland Naturalist. 81: 87-98; 1969.

Moir, W. H.; Ludwig, J. A. A classification of spruce-fir and mixed conifer habitat types of Arizona and New Mexico. Research Paper RM-207. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1979. 47 p.

Monserud, R. A. Height growth and site index curves for inland Douglas-fir based on stem analysis and forest habitat type. Forest Science. 30: 943-965; 1984a.

Monserud, R. A. Problems with site index: an opinionated review. In: Bockheim, J., ed. Forest land classification: experiences, problems, perspectives: Symposium proceedings; [dates and place of meeting unknown]. Madison, WI: University of Wisconsin, Department of Soil Science; 1984b: 167-180.

Monserud, R. A. Comparison of Douglas-fir site index and height growth curves in the Pacific Northwest. Canadian Journal of Forest Research. 15: 673-679; 1985.

Mueller-Dombois, D. The forest habitat types of southeastern Manitoba and their application to forest management. Canadian Journal of Botany. 42: 1417-1444; 1964.

Mueller-Dombois, D.; Ellenberg, H. Aims and methods of vegetation ecology. New York: John Wiley and Sons; 1974. 547 p.

Neiman, K. E., Jr. Soil discriminant functions for six habitat types in northern Idaho. Moscow, ID: University of Idaho; 1986. 174 p. Ph.D. dissertation.

Neiman, K. E.; Guerrero, E.; Ferguson, D. Reforestation problem analysis, Selway Ranger Dsitrict, Nezperce National Forest. Grangeville, ID: U.S. Department of Agriculture, Forest Service, Nez Perce National Forest; 1985. 45 p.

Nimlos, T. J.; Zuring, H. The distribution and thickness of volcanic ash in Montana. Northwest Science. 56(3): 190-198; 1982.

Ogilvie, R. T. Ecology of spruce forests of the east slope of the Rocky Mountains in Alberta. Pullman, WA: Washington State University; 1962. 189 p. Ph.D. dissertation.

Packee, E. C. Roosevelt elk (*Cervus canadensis roosevelti* Merriam)...a bibliography with comments pertinent to British Columbia. Forest Research Note 2. Vancouver, BC: MacMillan Bloedel Ltd.; 1975. 58 p.

Parker, T. Natural regeneration of western redcedar in northern Idaho. Forest Utilization Research Report. Moscow, ID: University of Idaho; 1979. 50 p.

Patterson, P. A.; Neiman, K. E.; Tonn, J. R. Field guide to forest plants of northern Idaho. General Technical Report INT-180. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 246 p.

Pengelly, W. L. Ecological effects of slash-disposal fires on the Coeur d'Alene National Forest, Idaho. Missoula, MT: U.S. Department of Agriculture, Forest Service; 1966. 23 p.

Peterson, E. B. The subalpine mountain hemlock zone. Part I: Phytocoenoses. In: Krajina, V. J., ed. Ecology of western North America. Vancouver, BC: University of British Columbia; 1965: 76-78. Vol. 1.

Pfister, R. D. Land capability assessment by habitat types. In: America's renewable resource potential—1975: the turning point; Proceedings, 1975 national convention of Society of American Foresters. Washington, DC: Society of American Foresters; 1976: 312-325.

Pfister, R. D. The use of habitat types in making silvicultural decisions. In: The scientific and technical basis for land classification; a joint technical session; 1980 October 7; Spokane, WA. Washington, DC: Society of American Foresters; 1980: 34-38.

Pfister, R. D. Habitat type classifications for managing western watersheds. In: Baumgartner, D. M., ed. Interior west watershed management: Proceedings of the symposium; 1980 April 8-10; Spokane, WA. Pullman, WA: Washington State University; 1981: 59-67.

Pfister, R. D.; Arno, S. F. Classifying forest habitat types based on potential climax vegetation. Forest Science. 26(1): 52-70; 1980.

Pfister, R. D.; Daubenmire, R. Ecology of lodgepole pine (*Pinus contorta* Dougl.). In: Management of lodgepole pine ecosystems: Symposium proceedings. Vol. 1. Pullman, WA: Washington State University; 1975: 27-46.

Pfister, R. D.; Kovalchik, B. L.; Arno, S. F.; Presby, R. C. Forest habitat types of Montana. General Technical Report INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 174 p.

Pierce, J. Wetland community type classification for west-central Montana. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1986. 78 p. Review draft.

Pierce, J. D. Food habits, movements, habitat selection and populations of moose in northcentral Idaho, and relationships to forest management. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1983. 205 p. M.S. thesis.

Poore, M. E. D. The method of successive approximation in descriptive ecology. Advances in Ecological Research. 1: 35-68; 1962.

Pyke, D. A.; Zamora, B. A. Relationships between overstory structure and understory production in the grand fir/myrtle boxwood habitat type of northcentral Idaho. Journal of Range Management. 35(6): 769-773; 1982.

Rehfeldt, G. E. Genetic differentiation of Douglas-fir populations from the Northern Rocky Mountains. Ecology. 59: 1264-1270; 1978.

Rehfeldt, G. E. Genetic variation in southern Idaho ponderosa pine progeny tests after 11 years. General Technical Report INT-75. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 12 p.

Rehfeldt, G. E. [Personal communication]. 1983. Moscow, ID: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Roe, A. L.; DeJarnette, G. M. Results of regeneration cutting in a spruce-subalpine fir stand. Research Paper INT-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1965. 14 p.

Romme, W. H. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs. 52(2): 199-221; 1982.

Root, R. A.; Habeck, J. R. A study of high elevational grassland communities in western Montana. The American Midland Naturalist. 87(1): 109-121; 1972.

Ross, S. H.; Savage, C. N. Idaho earth science geology, fossils, climate, water, and soils. Moscow, ID: Idaho Bureau of Mines and Geology; 1967. 271 p.

Scharosch, S. Predicting the probability of occurrence of selected shrub species in the understory of north and central Idaho forests. Moscow, ID: University of Idaho, College of Forestry, Wildlife and Range Sciences; 1984. 43 p. M.S. thesis.

Schmidt, W. C.; Shearer, R. C.; Roe, A. L. Ecology and silviculture of western larch forests. Technical Bulletin No. 1520. Washington, DC: U.S. Department of Agriculture, Forest Service; 1976. 96 p.

Soil Survey Staff. Preliminary soil survey manual. 430-V-55M. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1981. 480 p.

Space, R. The Clearwater story. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1964. 164 p. [Unpublished.]

Stage, A. R. Site curves for grand fir in the Inland Empire. Research Note 71. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1959. 4 p.

Stage, A. R. Prognosis Model for stand development. Research Paper INT-137. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 32 p.

Stage, A. R.; Alley, J. R. An inventory design using stand examinations for planning and programming timber management. Research Paper INT-126. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1973. 17 p.

Steele, B. M.; Cooper, S. V. Predicting site index and height for selected tree species of northern Idaho. Research Paper INT-365. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 16 p.

Steele, R. Red alder habitats in Clearwater County, Idaho. Moscow, ID: University of Idaho; 1971. 88 p. M.S. thesis.

Steele, R.; Arno, S. F.; Pfister, R. D. Preliminary forest habitat types of the Nez Perce National Forest. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 71 p. [Mimeo, unpublished.]

Steele, R.; Cooper, S. V.; Ondov, D. M.; Roberts, D.; Pfister, R. D. Forest habitat types of eastern Idaho-western Wyoming. General Technical Report INT-144. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 122 p.

Steele, R.; Geier-Hayes, K. Preliminary review: the grand fir/blue huckleberry habitat type: succession and management. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 54 p. Review draft.

Steele, R.; Geier-Hayes, K. The Douglas-fir/ninebark habitat type in central Idaho: succession and management. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 83 p. Review draft.

Steele, R.; Geier-Hayes, K. The Douglas-fir/pinegrass habitat type in central Idaho: succession and management. Boise, ID: U.S. Department of Agriculture, Forest Service, Intermountain Research Station and Intermountain Region; 1984. 124 p. Preliminary draft.

Steele, R.; Pfister, R. D.; Ryker, R. A.; Kittams, J. A. Forest habitat types of central Idaho. General Technical Report INT-114. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 138 p.

Stephens, F. R. Lodgepole pine-soil relations in the northwest Oregon Cascade Mountains. Journal of Forestry. 64: 184-186; 1966.

Stickney, P. Field identification of western Montana *Vacciniums*. Missoula, MT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station, Forestry Sciences Lab.; [n.d.]. 13 p. [Unpublished.]

Stickney, P. F. Vegetation response to clearcutting and broadcast burning on north and south slopes at Newman Ridge. In: Baumgartner, D. M., ed. Site preparation and fuels management on steep terrain: Proceedings of the symposium; 1982 February 15-17; Spokane, WA. Pullman, WA: Washington State University, Cooperative Extension; 1982: 119-124.

Stringer, P. W.; Laroi, G. H. The Douglas-fir forests of Banff and Jasper National Parks. Canadian Journal of Botany. 48(10): 1703-1726.

Tansley, A. G. The use and abuse of vegetational concepts and terms. Ecology. 16: 284-307; 1935.

Tarrant, R. F. Soil moisture and the distribution of lodgepole and ponderosa pine (a review of the literature). Research Paper 8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1953. 10 p.

Thornbury, W. D. Regional geomorphology of the United States. New York: John Wiley and Sons; 1965. 609 p.

Tisdale, E. W. Grazing use of forest lands in northern Idaho and adjacent areas. Proceedings of the Society of American Foresters; 1960: 150-153.

Tisdale, E. W. A preliminary classification of Snake River Canyon grasslands in Idaho. Station Note 32. Moscow, ID: University of Idaho, Forestry, Wildlife and Range Experiment Station; 1979. 8 p.

Tuhey, J. S. Stream bottom community classification for the Sawtooth Valley, Idaho. Moscow, ID: University of Idaho; 1981. 230 p. M.S. thesis.

U.S. Department of Agriculture, Soil Conservation Service. Soil taxonomy (a basic system of soil classification for making and interpreting soil surveys). Agriculture Handbook 436. Washington, DC: U.S. Department of Agriculture; 1975. 754 p.

Utzig, G.; McDonald, D.; Still, G.; Ketcheson, M.; Braumandl, T.; Warner, A. Ecological classification for the Nelson Forest Region (third approximation). Victoria, BC: Province of British Columbia, Ministry of Forests; 1983. 79 p.

Vogl, R. J. [Reply to Daubenmire 1966.] Science. 152: 546; 1966.

Volland, L. A. A multivariate classification of lodgepole pine type in central Oregon with implications for natural resource management. Fort Collins, CO: Colorado State University; 1974. 250 p. Ph.D. dissertation.

Volland, L. A. Plant communities of the central Oregon pumice zone. R-6 Area Guide 402. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1976. 113 p.

Wali, M. K.; Krajina, V. J. Vegetation-environment relationships of some sub-boreal spruce zone ecosystems in British Columbia. Vegetatio. 26(4-6): 237-381; 1973.

Walter, H. Vegetation of the earth in relation to climate and the eco-physiological conditions. New York: Springer-Verlag; 1973. 237 p.

Wellner, C. A. Fire history in the Northern Rocky Mountains. In: The role of fire in the Intermountain West: symposium proceedings. Missoula, MT: University of Montana, Forestry School; 1970a: 42-64.

Wellner, C. A. Regeneration problems of ponderosa pine in the Northern Rocky Mountains. In: Regeneration of ponderosa pine: symposium proceedings; 1969 September 11-12; [place of meeting unknown]. Corvallis, OR: Oregon State University, School of Forestry; 1970b: 5-11.

Wheeler, W. P.; Krueger, W. C.; Kavra, M. The effects of grazing on survival and growth of trees planted in a northeastern Oregon clearcut. Special Report 586. Corvallis, OR: Oregon State University, Agriculture Experiment Station; 1980: 28-31.

Whitaker, R. H. Gradient analysis of vegetation. Biological Reviews. 42: 207-264; 1967.

Williams, C. K.; Lillybridge, T. R. Forested plant associations of the Okanogan National Forest. R6-ECOL-132b-1983. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1983. 140 p.

Youngberg, C. T.; Dahms, W. S. Productivity indices for lodgepole pine on pumice soils. Journal of Forestry. 68: 90-94; 1970.

Youngblood, A. P.; Mauk, R. L. 1985. Coniferous forest habitat types of central and southern Utah. General Technical Report INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 89 p.

Zamora, B. A. Understory development in forest succession: an example from the Inland Northwest. In: Means, J. E., ed. Forest succession and stand development research in the Northwest. Corvallis, OR: Oregon State University, Forestry Research Laboratory; 1982: 63-69.

APPENDIX A: DISTRIBUTION OF SAMPLE STANDS BY SERIES, HABITAT TYPE, AND PHASE WITHIN NATIONAL FORESTS OF NORTHERN IDAHO (PLOTS NOT ACTUALLY ON NATIONAL FOREST LAND ARE REFERENCED TO THE NEAREST NATIONAL FOREST)

K = Kaniksu National Forest
CDA = Coeur d'Alene National Forest
STJ = St. Joe National Forest
CW = Clearwater National Forest
NP = Nez Perce National Forest
KOO = Kootenai National Forest
B = Bitterroot National Forest
EWA = Eastern Washington

	National Forest vicinity								
Habitat type-Phase	K	CDA	STJ	CW	NP	KOO	B	EWA	Total
***Tsuga heterophylla* (TSHE) Series**									
TSHE/GYDR	12	7	4	.	.	1	.	.	24
/ASCA-ARNU	4	2	.	.	.	.	.	.	6
/ASCA-MEFE	1	2	.	.	.	.	.	.	3
/ASCA-ASCA	5	25	6	.	.	.	.	.	36
/CLUN-MEFE	3	1	1	1	.	1	.	.	7
/CLUN-ARNU	11	.	.	.	.	.	.	.	11
/CLUN-XETE	6	6	.	.	.	2	.	.	14
/CLUN-CLUN	21	11	.	2	.	5	.	.	39
/XETE	3	.	.	.	.	.	.	.	3
									143
***Thuja plicata* (THPL) Series**									
THPL/OPHO	9	2	7	.	.	.	.	.	18
/ATFI-ADPE	.	.	1	8	5	.	.	.	14
/ATFI-ATFI	3	.	6	14	9	.	.	.	32
/ADPE	.	.	3	13	10	.	.	.	26
/GYDR	.	.	5	3	1	.	.	.	9
/ASCA-MEFE	.	.	5	2	.	.	.	.	7
/ASCA-TABR	.	.	1	2	5	.	.	.	8
/ASCA-ASCA	1	1	8	16	21	.	.	.	47
/CLUN-MEFE	.	.	4	5	2	.	.	.	11
/CLUN-TABR	.	.	.	.	8	.	.	.	8
/CLUN-XETE	.	.	.	2	5	.	.	.	7
/CLUN-CLUN	4	3	7	16	15	.	1	.	46
									233
***Tsuga mertensiana* (TSME) Series**									
TSME/STAM-LUHI	.	.	3	1	.	.	.	.	4
/STAM-MEFE	.	1	2	1	.	.	.	.	4
/CLUN-MEFE	.	3	7	13	.	.	.	.	23
/CLUN-XETE	.	.	5	1	.	.	1	1	8
/MEFE-LUHI	.	3	1	7	.	.	1	.	12
/MEFE-XETE	.	.	8	5	.	.	1	.	14
/XETE-LUHI	.	1	9	4	.	.	.	.	14
/XETE-VASC	.	.	4	4	.	.	1	.	9
/XETE-VAGL	.	1	7	4	.	.	3	.	15
									103
***Abies lasiocarpa* (ABLA) Series**									
ABLA/CACA-LEGL	.	.	.	2	6	.	.	.	8
/CACA-LICA	.	.	.	.	.	.	.	.	0
/CACA-VACA	.	.	.	2	2	.	.	.	4
/CACA-CACA	.	.	.	2	4	.	.	.	6
/STAM-MEFE	6	.	.	5	5	1	.	.	17
/STAM-LICA	1	1	1	1	10	.	.	.	14
/CLUN-MEFE	1	1	.	6	9	.	.	.	17
/CLUN-XETE	4	1	2	4	6	1	.	.	18
/CLUN-CLUN	1	.	.	1	1	.	.	.	3
/MEFE-LUHI	5	.	.	1	2	.	.	.	8
/MEFE-VASC	.	.	.	3	8	.	.	.	11
/MEFE-COOC	.	.	1	2	7	.	.	.	10
/MEFE-XETE	2	.	1	.	2	.	.	.	5
/VACA	.	.	.	.	+	.	.	.	+
/XETE-LUHI	3	.	.	3	10	.	2	.	18

(con.)

APPENDIX A (Con.)

Habitat type-Phase	K	CDA	STJ	CW	NP	KOO	B	EWA	Total
	National Forest vicinity								
/XETE-VASC	.	.	.	5	13	.	2	.	20
/XETE-COOC	.	.	.	3	13	.	.	.	16
/XETE-VAGL	3	.	2	5	6	.	.	.	16
/LUHI	1	.	.	.	5	.	.	.	6
/VAGL	.	.	.	.	2	.	.	.	2
/CARU	.	.	.	.	1	.	.	.	1
LALY-ABLA h.t.'s[1]	+	.	.	+	+	.	+	.	+
PIAL-ABLA h.t.'s[1]	.	.	.	+	+	+	+	.	+
									200
***Abies grandis* (ABGR) Series**									
ABGR/SETR	.	.	.	.	9	.	.	.	9
/ASCA-MEFE	.	.	.	1	11	.	.	.	12
/ASCA-TABR	.	.	.	1	20	.	.	.	21
/ASCA-ASCA	1	4	4	10	13	.	.	.	32
/CLUN-MEFE	.	.	.	3	14	.	.	.	17
/CLUN-TABR	.	.	.	.	11	.	.	.	11
/CLUN-XETE	2	4	3	4	25	.	.	.	38
/CLUN-PHMA	6	3	4	4	5	.	.	.	22
/CLUN-CLUN	1	3	1	7	14	.	1	.	27
/LIBO-LIBO	.	1	.	1	9	.	.	.	11
/LIBO-XETE	.	.	1	1	5	.	.	.	7
/XETE-COOC	.	.	.	2	13	.	.	.	15
/XETE-VAGL	1	.	1	2	14	.	1	.	19
/VAGL[1]	.	.	.	.	+	.	.	.	+
/PHMA-COOC	.	.	.	2	4	.	.	.	6
/PHMA-PHMA	2	7	3	3	3	.	.	.	18
/SPBE	.	1	1	2	4	.	.	.	8
									273
***Pseudotsuga menziesii* (PSME) Series**									
PSME/PHMA-SMST	4	2	.	8	4	.	.	1	19
/PHMA-PHMA	5	2	.	2	13	.	.	5	27
/VACA	2	.	.	.	2	.	.	.	4
/VAGL	.	.	.	.	.	.	1	.	1
/SYAL	.	.	.	.	.	3	.	4	7
/SPBE	.	.	.	.	4	.	.	3	7
/CARU-ARUV	3	.	.	.	1	.	.	3	7
/CARU-CARU	1	.	.	.	1	.	3	.	5
/CAGE	.	.	.	.	1	.	.	.	1
/FEID	.	.	.	.	2	.	.	.	2
/AGSP	.	.	.	.	3	.	.	.	3
									83
***Pinus ponderosa* (PIPO) Series**									
PIPO/PHMA	.	.	.	5	.	.	.	3	8
/SYAL	.	2	.	4	3	.	.	7	16
/FEID	.	1	.	.	11	.	.	2	14
/AGSP	.	.	.	.	6	.	.	.	6
									44
***Pinus contorta* (PICO) Series**									
PICO/VACA	.	.	.	.	2	.	.	.	2
/XETE	.	.	.	.	2	.	.	.	2
/VASC	.	.	.	.	7	.	.	.	7
									11

[1]No sampled stands recorded for northern Idaho, reconnaissance observations or hypothesized occurrence recorded as +.

APPENDIX B: OCCURRENCE AND ROLES OF TREE SPECIES BY HABITAT TYPE AS INTERPRETED FROM STAND DATA AND RECONNAISSANCE OBSERVATIONS

C = Major climax species   S = Major seral species   a = accidental
c = Minor climax species   s = Minor seral species   ( ) = occurring only locally
? = Status in question or conflicts with published results for same h.t. (or phase)

Series/Habitat type-Phase	PIPO	PSME	PICO	LAOC	ABGR	PIMO	PIEN	THPL	TSHE	ABLA	TSME	PIAL
***Tsuga heterophylla* (TSHE) Series**												
TSHE /GYDR	a	(s)	.	(S)	s	S	(s)	c	C	a	.	.
/ASCA-ARNU	a	(s)	a	(s)	S	s	.	C	C	.	.	.
/ASCA-MEFE	.	S	s	s	s	S	(S)	c	C	s	.	.
/ASCA-ASCA	a	S	a	s	S	S	(s)	c	C	.	.	.
/CLUN-MEFE	.	S	(S)	(S)	S	S	(s)	S	C	(S)	a	.
/CLUN-ARNU	a	S	(s)	S	S/(c)	(s)	a	(c)	C	.	.	.
/CLUN-XETE	a	S	(S)	(S)	S/(c)	S	S	s	C	s	a	.
/CLUN-CLUN	a	S	(s)	(S)	S/(c)	(S)	(S)	S	C	(s)	.	.
/XETE	.	.	s	s	.	?/(s)	S	a	C	S	(c)	.
***Thuja plicata* (THPL) Series**												
THPL /OPHO	.	a	.	a	(s)	s	(S)	C	(C)	a	.	.
/ATFI-ADPE	.	a	.	a	S	(s)	(s)	C	(C)	.	.	.
/ATFI-ATFI	.	(s)	.	a	S	(s)	S	C	(C)	(s)	.	.
/ADPE	.	s	.	(s)	S	(s)	a	C	(C)	.	.	.
/GYDR	.	(s)	a	(s)	S	s	s	C	a	a	.	.
/ASCA-MEFE	.	S	(S)	S	S	S	S	C	.	s	a	.
/ASCA-TABR	.	s	(s)	(S)	S	s	s	C	.	.	.	.
/ASCA-ASCA	(s)	S	a	(s)	S	s	s	C	.	a	a	.
/CLUN-MEFE	a	S	(S)	s	S	s	S	C	.	s	s	.
/CLUN-TABR	.	(s)	(s)	.	S	(s)	S	C	.	a	.	.
/CLUN-XETE	a	S	a	S	S	(s)	S	C	.	s	s	.
/CLUN-CLUN	(s)	S	(s)	S	S	(s)	(s)	C	.	s	a	.
***Tsuga mertensiana* (TSME) Series**												
TSME/STAM-LUHI	.	.	(s)	a	.	(s)	s	.	.	c	C	s
/STAM-MEFE	.	s	s	s	.	(s)	S	.	.	c	C	.
/CLUN-MEFE	.	s	(S)	s	(s)	s	S	.	.	S/c	C	a
/CLUN-XETE	.	S	S	S	(s)	s	S	.	.	S/(c)	C	.
/MEFE-LUHI	.	.	s	.	.	(s)	S	.	.	c	C	s
/MEFE-XETE	.	(s)	S	(S)	a	s	S	.	.	S/(c)	C	(s)
/XETE-LUHI	.	.	s	a	.	.	s	.	.	c	C	s
/XETE-VAGL	.	s	(S)	(s)	a	s	s	.	.	c	C	(S)
/LUHI	.	.	s	.	.	.	S	.	.	s	C	?/(s)
***Abies lasiocarpa* (ABLA) Series**												
ABLA /CACA-LEGL	.	a	S	(s)	a	.	S/(c)	.	.	C	.	(s)
/CACA-LICA	.	.	s	.	.	.	S/(c)	.	.	C	.	.
/CACA-VACA	.	.	S	.	.	.	s	.	.	C	.	.
/CACA-CACA	.	s	S	.	.	.	S/(c)	.	.	C	.	(s)
/STAM-MEFE	.	s	s	(s)	s	s	S/(c)	a	.	C	.	.
/STAM-LICA	.	s	S	(s)	s	?	S/(c)	.	.	C	.	.
/CLUN-MEFE	.	(S)	s	(s)	(S)	(s)	S/(c)	.	.	C	a	.
/CLUN-XETE	.	S	S	S	S	(S)	S/(c)	.	.	C	a	.
/CLUN-CLUN	.	s	S	S	S	?	S/(c)	.	a	C	.	.
/MEFE-LUHI	.	.	s	?	.	a	S/(c)	.	.	C	.	s
/MEFE-VASC	.	(s)	S	?	s	.	S/(c)	.	.	C	a	s
/MEFE-COOC	.	s	S	s	s	(s)	S/(c)	.	.	C	a	.
/MEFE-XETE	.	s	(S)	?	a	(s)	S/(c)	a	a	C	a	.
/VACA	.	s	S	.	a	.	s	.	.	C	.	.
/XETE-LUHI	.	.	S	.	.	.	c	.	.	C	.	S
/XETE-VASC	.	(s)	S	?	(s)	.	c	.	.	C	a	s
/XETE-COOC	.	S	S	s	S	(s)	S/(c)	.	.	C	.	a
/XETE-VAGL	.	S	S	(s)	(s)	(s)	s/(c)	.	.	C	a	(S)
/LUHI	.	.	a	.	.	.	c	.	.	C	.	S
/VAGL	.	S	S	s	.	.	S/(c)	.	.	C	.	(s)
/CARU	.	S	S	.	a	.	.	.	.	C	.	(s)
LALY-ABLA h.t.'s[1]	.	.	.	.	.	.	(c)	.	.	C	.	(C)
PIAL-ABLA h.t.'s[1]	.	.	.	.	.	.	(C)	.	.	C	.	C

(con.)

APPENDIX B (Con.)

Series/Habitat type-Phase	PIPO	PSME	PICO	LAOC	ABGR	PIMO	PIEN	THPL	TSHE	ABLA	TSME	PIAL
***Abies grandis* (ABGR) Series**												
ABGR/SETR	.	s	s	(s)	C	(s)	S	.	.	(c)	.	.
/ASCA-MEFE	a	S	s	(s)	C	(s)	S	.	.	(c)	.	.
/ASCA-TABR	.	s	.	(s)	C	(s)	S	a	.	(c)	.	.
/ASCA-ASCA	s	S	s	s	C	s	(s)	a	.	a	.	.
/CLUN-MEFE	a	S	S	(S)	C	s	S	.	.	(c)	.	.
/CLUN-TABR	.	S	(s)	s	C	(s)	S	.	.	(c)	.	.
/CLUN-XETE	s	S	S	S	C	s	s	.	.	(c)	.	.
/CLUN-CLUN	s	S	s	s	C	s	(s)	a	.	a	.	.
/CLUN-PHMA	S	S	s	s	C	s	.	a	.	a	.	.
/LIBO-LIBO	S	S	S	s	C	(s)	s	.	.	(c)	.	.
/LIBO-XETE	(S)	S	S	S	C	(s)	S	.	.	(c)	.	.
/XETE-COOC	(S)	S	S	(s)	C	.	s	.	.	c	.	.
/XETE-VAGL	s	S	S	(s)	C	(s)	s	.	.	c	.	.
/VAGL	(s)	S	S	(s)	C	.	s	.	.	(c)	.	.
/PHMA-COOC	s	S	(s)	(s)	C	(s)	.	.	.	.	.	.
/PHMA-PHMA	S	S	(s)	(S)	C	a	.	.	.	.	.	.
/SPBE	S	S	(s)	(s)	C	(s)	a	.	.	.	.	.
***Pseudotsuga menziesii* (PSME) Series**												
PSME/PHMA-SMST	S	C	s	S	a	.	.	.	.	.	.	.
/PHMA-PHMA	S	C	(s)	a	a	.	.	.	.	.	.	.
/VACA	S	C	S	s	.	.	.	.	.	.	.	.
/VAGL	(s)	C	S	(s)	a	.	.	.	.	.	.	.
/SYAL	S	C	(s)	(s)	.	.	.	.	.	.	.	.
/SPBE	S	C	(s)	.	.	.	.	.	.	.	.	.
/CARU-ARUV	S	C	S	(S)	.	.	.	.	.	.	.	.
/CARU-CARU	(s)	C	s	.	.	.	.	.	.	.	.	.
/CAGE	c	C	s	.	.	.	.	.	.	.	.	.
/FEID	S(c)	C	.	.	.	.	.	.	.	.	.	.
/AGSP	S(c)	C	.	.	.	.	.	.	.	.	.	.
***Pinus ponderosa* (PIPO) Series**												
PIPO/PHMA	C	a	.	.	.	.	.	.	.	.	.	.
/SYAL	C	a	.	.	.	.	.	.	.	.	.	.
/FEID	C	a	.	.	.	.	.	.	.	.	.	.
/AGSP	C	.	.	.	.	.	.	.	.	.	.	.
***Pinus contorta* (PICO) Series**												
PICO/VACA	.	s	S	.	s	.	s	.	.	C	.	.
/XETE	.	s	S	(s)	s	(s)	s	.	.	C	.	(s)
/VASC	.	.	C	.	a	.	a	.	.	a	.	.

[1]No recorded data from northern Idaho, values from Pfister and others (1977).

APPENDIX C: CONSTANCY AND AVERAGE COVERAGE (PERCENT) OF IMPORTANT PLANTS IN NORTHERN IDAHO FOREST HABITAT TYPES AND PHASES

ADP abbrev.	Scientific name	Common name
	Tree Species	
1 ABIGRA	*Abies grandis*	grand fir
2 ABILAS	*Abies lasiocarpa*	subalpine fir
3 BETPAP	*Betula papyrifera*	paper birch
6 LAROCC	*Larix occidentalis*	western larch
7 PICENG	*Picea engelmannii*	Engelmann spruce
9 PINALB	*Pinus albicaulis*	whitebark pine
10 PINCON	*Pinus contorta*	lodgepole pine
12 PINMON	*Pinus monticola*	western white pine
13 PINPON	*Pinus ponderosa*	ponderosa pine
16 PSEMEN	*Pseudotsuga menziesii*	Douglas-fir
17 THUPLI	*Thuja plicata*	western redcedar
18 TSUHET	*Tsuga heterophylla*	western hemlock
19 TSUMER	*Tsuga mertensiana*	mountain hemlock
	Shrub Species	
102 ACEGLA	*Acer glabrum*	Rocky Mountain maple
104 ALNSIN	*Alnus sinuata*	Sitka alder
105 AMEALN	*Amelanchier alnifolia*	serviceberry
110 CRADOU	*Crataegus douglasii*	black hawthorn
111 HOLDIS	*Holodiscus discolor*	ocean-spray
113 LEDGLA	*Ledum glandulosum*	Labrador tea
115 LONUTA	*Lonicera utahensis*	Utah honeysuckle
116 MENFER	*Menziesia ferruginea*	fool's huckleberry
117 OPLHOR	*Oplopanax horridum*	devil's club
118 PACMYR	*Pachistima myrsinites*	pachistima
119 PHILEW	*Philadelphus lewisii*	syringa
122 PHYMAL	*Physocarpus malvaceus*	ninebark
124 PRUVIR	*Prunus virginiana*	common chokecherry
127 RHOALB	*Rhododendron albiflorum*	white rhododendron
130 RIBLAC	*Ribes lacustre*	prickly currant
133 ROSBYM	*Rosa gymnocarpa*	baldhip rose
161 ROSNUT	*Rosa nutkana*	Nootka rose
134 ROSWOO	*Rosa woodsii*	pearhip rose
136 RUBPAR	*Rubus parviflorus*	western thimbleberry
137 SALSCO	*Salix scouleriana*	Scouler willow
142 SPIBET	*Spiraea betulifolia*	white spiraea
143 SYMALB	*Symphoricarpos albus*	common snowberry
144 TAXBRE	*Taxus brevifolia*	Pacific yew
146 VACGLA	*Vaccinium globulare*	blue huckleberry
194 VACMEM	*Vaccinium membranaceum*	big huckleberry
	Dwarf Shrubs and Low Woody Plants	
201 ARCUVA	*Arctostaphylos uva-ursi*	bearberry
203 BERREP	*Berberis repens*	creeping Oregon grape
205 GAUHUM	*Gaultheria humifusa*	western wintergreen
206 LINBOR	*Linnaea borealis*	twinflower
219 PHYEMP	*Phyllodoce empetriformis*	red mountain-heather
218 SATDOU	*Satureja douglasii*	yerba buena
145 VACCAE	*Vaccinium caespitosum*	dwarf huckleberry
147 VACMYR	*Vaccinium myrtillus*	dwarf bilberry
148 VACSCO	*Vaccinium scoparium*	grouse whortleberry
	Ferns and Allied Taxa	
260 ADIPED	*Adiantum pedatum*	maidenhair fern
251 ATHFIL	*Athyrium filix-femina*	ladyfern
255 GYMDRY	*Gymnocarpium dryopteris*	oak-fern
258 POLMUN	*Polystichum munitum*	western swordfern
259 PTEAQU	*Pteridium aquilinum*	bracken fern

(con.)

APPENDIX C (Con.)

ADP abbrev.	Scientific name	Common name
	Graminoids	
301 AGRSPI	*Agropyron spicatum*	bluebunch wheatgrass
304 BROVUL	*Bromus vulgaris*	Columbia brome
305 CALCAN	*Calamagrostis canadensis*	bluejoint reedgrass
307 CALRUB	*Calamagrostis rubescens*	pinegrass
309 CARGEY	*Carex geyeri*	elk sedge
311 CARROS	*Carex rossii*	Ross sedge
317 FESIDA	*Festuca idahoensis*	Idaho fescue
325 LUZHIT	*Luzula hitchcockii*	smooth woodrush
	Perennial Forbs	
401 ACHMIL	*Achillea millefolium*	common yarrow
402 ACTRUB	*Actaea rubra*	baneberry
403 ADEBIC	*Adenocaulon bicolor*	trail-plant
407 ANEPIP	*Anemone piperi*	windflower
418 ARANUD	*Aralia nudicaulis*	wild sarsaparilla
420 AREMAC	*Arenaria macrophylla*	bigleaf sandwort
421 ARNCOR	*Arnica cordifolia*	heartleaf arnica
422 ARNLAT	*Arnica latifolia*	mountain arnica
564 ASACAU	*Asarum caudatum*	wild ginger
426 ASTCON	*Aster conspicuus*	showy aster
431 BALSAM	*Balsamorhiza sagittata*	arrowleaf balsamroot
442 CHIUMB	*Chimaphila umbellata*	prince's pine
445 CIRALP	*Circaea alpina*	alpine circaea
447 CLIUNI	*Clintonia uniflora*	queencup beadlily
449 COPOCC	*Coptis occidentalis*	western goldthread
452 CORCAN	*Cornus canadensis*	bunchberry dogwood
454 DISHOO	*Disporum hookeri*	Hooker fairy-bell
455 DISTRA	*Disporum trachycarpum*	wartberry fairy-bell
458 DODJEF	*Dodecatheon jeffreyi*	Jeffrey's shooting star
465 FRAVES	*Fragaria vesca*	woods strawberry
467 FRAGAR	*Fragaria* species	strawberries
466 FRAVIR	*Fragaria virginiana*	strawberry
471 GALTRI	*Galium triflorum*	northern bedstraw
476 GOOOBL	*Goodyera oblongifolia*	rattlesnake-plantain
482 HEUCYL	*Heuchera cylindrica*	roundleaf alumroot
489 LIGCAN	*Ligusticum canbyi*	Canby's licorice-root
800 LIGVER	*Ligusticum verticillatum*	licorice-root
647 MERPAN	*Mertensia paniculata*	tall bluebells
501 MITBRE	*Mitella breweri*	Brewer's mitrewort
649 MITPEN	*Mitella pentandra*	alpine mitrewort
502 MITSTA	*Mitella stauropetala*	side-flowered mitrewort
505 OSMCHI	*Osmorhiza chilensis*	mountain sweet-cicely
507 PEDBRA	*Pedicularis bracteosa*	bracted lousewort
508 PEDCON	*Pedicularis contorta*	coiled-beak lousewort
509 PEDRAC	*Pedicularis racemosa*	leafy lousewort
519 POLPUL	*Polemonium pulcherrimum*	Jacob's ladder
526 PYRASA	*Pyrola asarifolia*	common pink wintergreen
529 PYRSEC	*Pyrola secunda*	one-sided wintergreen
539 SENTRI	*Senecio triangularis*	arrowleaf groundsel
542 SMIRAC	*Smilacina racemosa*	false solomon's seal
543 SMISTE	*Smilacina stellata*	starry Solomon seal
546 STRAMP	*Streptopus amplexifolius*	twisted-stalk
810 SYNPLA	*Synthyris platycarpa*	evergreen synthyris
547 THAOCC	*Thalictrum occidentale*	western meadowrue
548 TIATRI	*Tiarella trifoliata*	coolwort foamflower
563 TRACAR	*Trautvetteria caroliniensis*	false bugbane
560 TRIOVA	*Trillium ovatum*	white trillium
551 VALSIT	*Valeriana sitchensis*	Sitka valerian
552 VERVIR	*Veratrum viride*	American false helebore
554 VIOADU	*Viola adunca*	hook violet
556 VIOGLA	*Viola glabella*	pioneer violet
557 VIOORB	*Viola orbiculata*	round-leaved violet
558 XERTEN	*Xerophyllum tenax*	beargrass

SERIES H.T. PHASE	TSHE GYDR	TSHE ASCA ARNU	TSHE ASCA MEFE	TSHE ASCA ASCA	TSHE CLUN ARNU	TSHE CLUN MEFE	TSHE CLUN XETE	TSHE CLUN CLUN	TSHE MEFE	
NO. OF PLOTS	N= 24	N= 7	N= 3	N= 39	N= 14	N= 9	N= 15	N= 38	N= 3	N=
TREE SPECIES										
1 ABIGRA	5(14)	9(52)	7(T)	9(49)	7(19)	6(47)	7(21)	7(20)	-( )	
2 ABILAS	2(5)	-( )	10(13)	1(T)	-( )	4(50)	5(17)	2(27)	10(46)	
3 BETPAP	1(T)	4(13)	-( )	+(3)	2(7)	-( )	-( )	1(18)	-( )	
6 LAROCC	3(12)	4(5)	7(2)	5(8)	6(25)	4(34)	7(19)	6(19)	7(19)	
7 PICENG	3(6)	-( )	10(6)	2(1)	3(5)	6(18)	3(15)	3(21)	3(3)	
9 PINALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
10 PINCON	-( )	1(T)	-( )	2(1)	3(5)	4(11)	5(13)	2(3)	3(15)	
12 PINMON	7(8)	7(3)	7(8)	6(10)	8(10)	8(5)	7(11)	6(9)	-( )	
13 PINPON	-( )	-( )	-( )	1(7)	-( )	-( )	1(T)	1(T)	-( )	
16 PSEMEN	2(3)	4(10)	3(15)	5(21)	5(35)	8(17)	5(23)	5(28)	-( )	
17 THUPLI	6(48)	10(45)	-( )	5(36)	9(49)	8(17)	7(33)	9(37)	-( )	
18 TSUHET	9(72)	10(54)	10(73)	10(36)	9(35)	9(17)	10(38)	10(53)	10(62)	
19 TSUMER	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	
SHRUB SPECIES										
102 ACEGLA	6(5)	9(1)	3(T)	5(3)	4(5)	3(6)	4(14)	3(T)	-( )	
104 ALNSIN	+(3)	4(5)	7(3)	1(T)	1(T)	6(8)	1(8)	+(T)	-( )	
105 AMEALN	3(T)	6(T)	-( )	5(T)	5(T)	2(T)	3(T)	4(T)	-( )	
110 CRADOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
111 HOLDIS	-( )	1(T)	-( )	2(2)	4(T)	-( )	2(T)	1(T)	-( )	
113 LEDGLA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
115 LONUTA	8(2)	9(T)	10(1)	7(T)	6(T)	10(3)	9(2)	9(1)	7(T)	
116 MENFER	6(3)	1(T)	10(27)	2(1)	3(T)	10(30)	7(2)	4(T)	10(53)	
117 OPLHOR	3(1)	6(1)	-( )	2(T)	1(T)	-( )	1(T)	+(T)	-( )	
118 PACMYR	7(5)	7(8)	10(7)	7(4)	6(7)	6(18)	9(14)	7(5)	-( )	
119 PHILEW	-( )	1(T)	-( )	1(2)	-( )	-( )	-( )	-( )	-( )	
122 PHYMAL	-( )	1(3)	-( )	2(6)	1(T)	1(T)	-( )	1(T)	-( )	
124 PRUVIR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
127 RHOALB	+(T)	-( )	-( )	-( )	-( )	3(6)	-( )	1(T)	3(38)	
130 RIBLAC	1(T)	-( )	-( )	1(T)	-( )	2(T)	-( )	1(T)	-( )	
133 ROSGYM	7(2)	10(T)	-( )	8(2)	10(1)	3(1)	6(3)	5(T)	-( )	
161 ROSNUT	-( )	1(T)	-( )	+(T)	-( )	1(T)	-( )	+(3)	-( )	
134 ROSWOO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
136 RUBPAR	5(2)	4(T)	7(T)	5(3)	6(T)	4(1)	4(1)	3(2)	-( )	
137 SALSCO	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	
142 SPIBET	+(T)	3(T)	-( )	3(T)	4(6)	3(1)	5(1)	3(1)	-( )	
143 SYMALB	1(T)	6(T)	3(T)	5(6)	3(T)	1(T)	1(T)	1(T)	-( )	
144 TAXBRE	5(15)	3(T)	7(T)	2(1)	1(15)	1(T)	2(22)	2(4)	-( )	
146 VACGLO	3(3)	4(T)	10(19)	6(2)	6(4)	7(25)	9(28)	7(8)	10(18)	
194 VACMEM	6(8)	3(20)	-( )	1(3)	2(18)	3(34)	1(T)	2(3)	-( )	
LOW WOODY PLANTS AND DWARF SHRUBS										
201 ARCUVA	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	+(T)	-( )	
203 BERREP	+(T)	1(T)	-( )	3(1)	4(4)	-( )	1(2)	2(T)	-( )	
205 GAUHUM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
206 LINBOR	8(11)	9(14)	3(15)	8(14)	10(17)	4(27)	8(5)	8(14)	-( )	
219 PHYEMP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
218 SATDOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
145 VACCAE	1(T)	-( )	-( )	-( )	1(T)	-( )	-( )	+(T)	-( )	
147 VACMYR	+(T)	-( )	3(T)	+(3)	1(T)	1(15)	-( )	+(T)	3(T)	
148 VACSCO	+(T)	-( )	-( )	-( )	-( )	1(63)	-( )	1(2)	-( )	
FERNS AND ALLIED TAXA										
260 ADIPED	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	
251 ATHFIL	6(2)	6(T)	3(T)	4(T)	2(T)	-( )	3(T)	2(T)	-( )	
255 GYMDRY	10(25)	6(T)	3(T)	3(T)	4(T)	3(T)	2(T)	3(T)	-( )	
258 POLMUN	2(1)	4(1)	3(T)	4(1)	1(T)	2(T)	1(T)	2(T)	-( )	
259 PTEAQU	3(1)	1(T)	-( )	4(1)	2(5)	3(1)	3(T)	2(5)	-( )	
GRAMINOIDS										
301 AGRSPI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
304 BROVUL	6(2)	6(T)	7(2)	9(T)	4(T)	7(T)	5(T)	4(T)	-( )	
305 CALCAN	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	+(T)	-( )	
307 CALRUB	-( )	-( )	-( )	1(T)	2(2)	2(2)	1(T)	1(5)	-( )	
309 CARGEY	-( )	-( )	-( )	1(T)	-( )	2(2)	-( )	+(T)	-( )	
311 CARROS	-( )	-( )	-( )	1(T)	2(T)	-( )	-( )	-( )	-( )	
317 FESIDA	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	
325 LUZHIT	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	7(T)	

(con.)

SERIES H.T. PHASE	TSHE GYDR	TSHE ASCA ARNU	TSHE ASCA MEFE	TSHE ASCA ASCA	TSHE CLUN ARNU	TSHE CLUN MEFE	TSHE CLUN XETE	TSHE CLUN CLUN	TSHE MEFE	
NO. OF PLOTS	N= 24	N= 7	N= 3	N= 39	N= 14	N= 9	N= 15	N= 38	N= 3	N=
PERENNIAL FORBS										
401 ACHMIL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	
402 ACTRUB	3(T)	4(T)	-( )	3(T)	-( )	-( )	-( )	-( )	-( )	
403 ADEBIC	5(T)	10(3)	7(T)	9(1)	5(T)	2(T)	3(T)	3(T)	-( )	
407 ANEPIP	3(1)	4(T)	-( )	5(T)	-( )	6(T)	1(T)	1(T)	-( )	
418 ARANUD	1(10)	10(3)	-( )	1(T)	10(7)	-( )	-( )	+(T)	-( )	
420 AREMAC	-( )	-( )	-( )	1(T)	-( )	-( )	1(T)	1(T)	-( )	
421 ARNCOR	1(22)	-( )	-( )	-( )	1(T)	-( )	-( )	+(T)	-( )	
422 ARNLAT	+(T)	3(T)	10(34)	2(T)	-( )	6(29)	3(21)	1(18)	-( )	
564 ASACAU	5(2)	10(8)	10(T)	9(4)	-( )	-( )	-( )	-( )	-( )	
426 ASTCON	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
431 BALSAG	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
442 CHIUMB	4(T)	10(1)	3(T)	7(T)	8(T)	4(1)	7(T)	8(2)	-( )	
445 CIRALP	+(T)	-( )	-( )	1(1)	-( )	-( )	-( )	-( )	-( )	
447 CLIUNI	10(6)	10(5)	10(2)	10(2)	10(6)	10(4)	10(1)	10(2)	3(T)	
449 COPOCC	5(28)	3(8)	7(15)	9(16)	3(14)	4(15)	4(9)	4(9)	-( )	
452 CORCAN	3(8)	3(2)	-( )	2(2)	5(5)	4(8)	1(T)	2(6)	-( )	
454 DISHOO	9(4)	10(3)	3(T)	8(2)	6(3)	4(T)	5(T)	5(T)	-( )	
455 DISTRA	-( )	-( )	-( )	1(T)	2(T)	-( )	1(T)	1(T)	-( )	
458 DODJEF	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
465 FRAVES	-( )	1(T)	-( )	2(2)	1(T)	-( )	1(T)	1(T)	-( )	
467 FRAGAR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
466 FRAVIR	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	
471 GALTRI	4(1)	4(T)	7(T)	7(1)	6(T)	7(T)	1(T)	2(T)	-( )	
476 GOOOBL	7(T)	9(T)	7(T)	5(T)	6(T)	6(1)	7(T)	7(T)	7(T)	
482 HEUCYL	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	+(T)	-( )	
489 LIGCAN	+(T)	1(T)	3(T)	+(T)	-( )	1(T)	-( )	+(T)	-( )	
800 LIGVER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
647 MERPAN	+(T)	-( )	-( )	+(T)	-( )	1(T)	-( )	-( )	-( )	
501 MITBRE	-( )	-( )	3(T)	-( )	-( )	-( )	-( )	-( )	-( )	
649 MITPEN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
502 MITSTA	2(1)	-( )	3(T)	2(T)	1(T)	2(T)	1(2)	2(T)	-( )	
505 OSMCHI	5(T)	7(T)	10(T)	7(T)	4(T)	4(T)	3(T)	2(T)	-( )	
507 PEDBRA	+(T)	-( )	-( )	+(T)	-( )	3(T)	1(T)	-( )	-( )	
508 PEDCON	+(T)	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	
509 PEDRAC	+(T)	-( )	-( )	+(T)	-( )	1(T)	1(T)	-( )	-( )	
519 POLPUL	+(T)	-( )	3(T)	+(T)	-( )	-( )	1(T)	+(T)	-( )	
526 PYRASA	6(T)	4(T)	3(T)	3(T)	3(T)	6(2)	7(T)	6(T)	7(2)	
529 PYRSEC	5(T)	6(T)	3(T)	5(T)	5(T)	7(3)	7(T)	6(T)	10(T)	
539 SENTRI	1(1)	3(T)	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	
542 SMIRAC	1(T)	-( )	3(T)	2(T)	1(T)	3(T)	1(T)	1(T)	-( )	
543 SMISTE	10(3)	10(3)	10(1)	10(4)	9(1)	3(14)	7(T)	5(T)	-( )	
546 STRAMP	4(T)	1(T)	-( )	1(T)	-( )	2(T)	1(T)	1(T)	-( )	
810 SYNPLA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
547 THAOCC	2(T)	1(T)	10(T)	4(T)	4(T)	6(1)	4(T)	1(T)	-( )	
548 TIATRI	9(9)	9(4)	10(5)	9(7)	4(4)	10(7)	7(2)	7(3)	-( )	
563 TRACAR	2(4)	1(T)	-( )	+(T)	1(T)	1(T)	-( )	-( )	-( )	
560 TRIOVA	9(T)	6(T)	10(T)	7(T)	4(T)	4(T)	5(T)	5(T)	-( )	
551 VALSIT	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
552 VERVIR	1(T)	1(T)	-( )	1(T)	-( )	-( )	-( )	1(T)	-( )	
554 VIOADU	-( )	1(T)	-( )	2(T)	-( )	-( )	-( )	+(T)	-( )	
556 VIOGLA	3(1)	1(T)	-( )	2(T)	1(T)	-( )	-( )	+(T)	-( )	
557 VIOORB	8(1)	9(1)	7(T)	6(T)	8(T)	10(2)	8(T)	9(T)	3(T)	
558 XERTEN	3(T)	-( )	10(5)	2(T)	-( )	7(16)	10(30)	4(T)	10(70)	

CODE TO CONSTANCY VALUES

+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

(con.)

APPENDIX C (Con.)

SERIES H.T. PHASE	THPL OPHO	THPL ATFI ATFI	THPL ATFI ADPE	THPL ADPE	THPL GYDR	THPL ASCA MEFE	THPL ASCA TABR	THPL ASCA ASCA	THPL CLUN MEFE	THPL CLUN TABR	THPL CLUN XETE	THPL CLUN CLUN	
NO. OF PLOTS	N= 19	N= 34	N= 13	N= 30	N= 12	N= 7	N= 8	N= 48	N= 11	N= 8	N= 9	N= 47	N=
TREE SPECIES													
1 ABIGRA	3(4)	6(25)	8(12)	8(26)	9(41)	10(27)	10(28)	10(46)	9(34)	10(47)	9(31)	9(49)	
2 ABILAS	1(2)	2(20)	-( )	-( )	2(6)	6(5)	-( )	1(8)	5(2)	1(T)	3(25)	1(T)	
3 BETPAP	-( )	+(3)	-( )	1(T)	-( )	-( )	-( )	1(17)	-( )	-( )	-( )	1(12)	
6 LAROCC	1(T)	1(1)	-( )	2(10)	2(2)	9(25)	4(14)	3(4)	7(8)	-( )	6(22)	4(16)	
7 PICENG	2(18)	6(13)	2(2)	+(T)	7(9)	9(29)	5(2)	4(3)	9(23)	9(9)	8(7)	2(4)	
9 PINALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
10 PINCON	-( )	-( )	-( )	+(T)	1(T)	3(20)	1(3)	+(19)	4(30)	1(T)	3(18)	2(8)	
12 PINMON	4(3)	3(4)	2(2)	3(7)	4(4)	6(T)	5(5)	3(5)	5(10)	2(T)	4(T)	4(7)	
13 PINPON	-( )	+(T)	-( )	+(T)	-( )	-( )	-( )	1(5)	2(2)	-( )	-( )	2(8)	
16 PSEMEN	-( )	1(15)	2(T)	3(12)	2(5)	9(20)	2(3)	6(23)	7(16)	6(4)	8(13)	8(21)	
17 THUPLI	9(59)	9(65)	10(60)	10(60)	10(75)	10(33)	10(73)	10(50)	9(29)	10(53)	10(31)	10(43)	
18 TSUHET	6(51)	2(38)	2(20)	3(20)	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	1(3)	
19 TSUMER	-( )	+(T)	-( )	-( )	-( )	1(T)	-( )	1(1)	5(2)	-( )	2(8)	-( )	
SHRUB SPECIES													
102 ACEGLA	6(1)	5(4)	7(2)	6(2)	8(5)	7(7)	6(3)	8(4)	3(1)	1(T)	1(T)	6(8)	
104 ALNSIN	1(T)	2(14)	-( )	+(T)	2(T)	4(2)	-( )	1(T)	5(11)	-( )	2(9)	1(6)	
105 AMEALN	1(T)	2(T)	3(4)	4(T)	5(T)	1(T)	6(1)	6(T)	3(2)	4(T)	3(T)	6(T)	
110 CRADOU	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	+(T)	
111 HOLDIS	-( )	+(T)	2(1)	2(T)	-( )	-( )	-( )	2(2)	-( )	-( )	-( )	3(1)	
113 LEDGLA	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	1(15)	-( )	-( )	-( )	
115 LONUTA	5(T)	4(T)	4(T)	7(T)	8(1)	9(3)	7(3)	7(1)	8(3)	9(4)	8(1)	7(T)	
116 MENFER	2(10)	5(5)	2(T)	2(T)	7(8)	10(20)	5(T)	3(1)	10(40)	6(2)	7(2)	2(3)	
117 OPLHOR	10(39)	1(T)	5(2)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
118 PACMYR	3(T)	1(T)	1(T)	-( )	5(2)	6(23)	7(T)	3(3)	5(17)	2(9)	4(10)	4(7)	
119 PHILEW	-( )	+(3)	2(T)	1(T)	-( )	-( )	-( )	2(3)	-( )	-( )	-( )	2(4)	
122 PHYMAL	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	1(12)	
124 PRUVIR	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	+(T)	
127 RHOALB	1(T)	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
130 RIBLAC	2(2)	4(2)	2(T)	+(T)	5(T)	6(T)	-( )	1(T)	4(T)	-( )	2(8)	1(T)	
133 ROSGYM	3(T)	4(1)	7(T)	7(T)	7(T)	3(T)	5(1)	8(2)	6(2)	7(1)	6(2)	9(4)	
161 ROSNUT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
134 ROSWOO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	
136 RUBPAR	4(1)	6(2)	5(T)	7(1)	8(2)	9(4)	4(T)	6(3)	7(3)	4(T)	6(4)	6(4)	
137 SALSCO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	2(9)	-( )	-( )	+(3)	
142 SPIBET	-( )	1(4)	-( )	2(T)	2(T)	3(T)	-( )	4(1)	3(1)	4(T)	3(5)	5(3)	
143 SYMALB	2(T)	4(5)	7(T)	5(2)	2(2)	-( )	4(T)	6(3)	2(T)	-( )	2(T)	6(5)	
144 TAXBRE	5(8)	4(15)	5(6)	5(6)	5(34)	4(T)	10(18)	3(1)	3(18)	10(37)	4(2)	2(1)	
146 VACGLO	2(5)	5(3)	2(2)	4(T)	7(3)	10(16)	5(1)	5(3)	10(39)	9(12)	9(28)	6(7)	
194 VACMEM	3(8)	1(3)	2(T)	3(T)	2(38)	-( )	2(3)	2(3)	-( )	-( )	1(3)	+(2)	
LOW WOODY PLANTS AND DWARF SHRUBS													
201 ARCUVA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
203 BERREP	-( )	-( )	1(T)	+(T)	1(T)	-( )	-( )	1(3)	2(T)	1(T)	3(T)	4(2)	
205 GAUHUM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
206 LINBOR	2(2)	4(5)	5(7)	8(15)	8(4)	4(1)	6(14)	7(13)	8(9)	9(21)	7(8)	9(15)	
219 PHYEMP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
218 SATDOU	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	+(T)	
145 VACCAE	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(2)	
147 VACMYR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	
148 VACSCO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
FERNS AND ALLIED TAXA													
260 ADIPED	4(6)	3(1)	10(32)	10(23)	4(T)	1(T)	1(T)	2(T)	-( )	-( )	-( )	1(T)	
251 ATHFIL	9(25)	10(45)	10(13)	5(2)	5(1)	6(1)	5(T)	2(T)	3(T)	2(T)	-( )	+(T)	
255 GYMDRY	10(41)	6(20)	10(13)	5(4)	10(19)	4(T)	4(T)	1(T)	3(T)	1(T)	-( )	+(T)	
258 POLMUN	4(2)	3(2)	8(3)	9(13)	7(3)	4(1)	7(T)	5(1)	5(T)	2(T)	-( )	4(2)	
259 PTEAQU	1(2)	4(2)	4(4)	4(1)	1(T)	3(2)	2(T)	4(2)	1(T)	1(T)	2(T)	4(2)	
GRAMINOIDS													
301 AGRSPI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
304 BROVUL	7(1)	7(T)	7(1)	8(1)	7(T)	10(T)	7(T)	7(3)	5(T)	1(T)	3(1)	6(T)	
305 CALCAN	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
307 CALRUB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	2(T)	-( )	1(15)	1(3)	
309 CARGEY	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	1(1)	
311 CARROS	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	+(T)	-( )	-( )	-( )	-( )	
317 FESIDA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
325 LUZHIT	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	

APPENDIX C (Con.)

SERIES H.T. PHASE	THPL OPHO	THPL ATFI ATFI	THPL ATFI ADPE	THPL ADPE	THPL GYDR	THPL ASCA MEFE	THPL ASCA TABR	THPL ASCA ASCA	THPL CLUN MEFE	THPL CLUN TABR	THPL CLUN XETE	THPL CLUN CLUN	
NO. OF PLOTS	N= 19	N= 34	N= 13	N= 30	N= 12	N= 7	N= 8	N= 48	N= 11	N= 8	N= 9	N= 47	N=
PERENNIAL FORBS													
401 ACHMIL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	+(T)	
402 ACTRUB	6(T)	[illegible](3)	5(T)	4(T)	3(T)	3(T)	1(T)	3(5)	1(T)	-( )	1(T)	1(T)	
403 ADEBIC	8(T)	8(6)	9(5)	10(6)	6(T)	4(1)	9(5)	8(4)	2(T)	4(T)	2(T)	6(2)	
407 ANEPIP	5(1)	6(2)	8(1)	8(2)	8(1)	10(T)	10(1)	8(2)	9(1)	9(2)	9(T)	7(T)	
418 ARANUD	1(3)	+(3)	-( )	-( )	-( )	-( )	-( )	+(33)	-( )	-( )	-( )	+(T)	
420 AREMAC	-( )	1(T)	2(T)	3(1)	-( )	-( )	4(T)	2(1)	1(T)	-( )	2(T)	1(T)	
421 ARNCOR	-( )	1(T)	1(T)	1(2)	2(19)	3(8)	2(T)	1(2)	2(33)	2(2)	1(3)	2(15)	
422 ARNLAT	-( )	1(2)	-( )	1(T)	4(14)	7(17)	2(8)	2(5)	5(22)	1(15)	7(22)	1(4)	
564 ASACAU	7(8)	9(11)	10(8)	9(8)	8(3)	10(3)	10(7)	10(4)	-( )	1(T)	-( )	2(T)	
426 ASTCON	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	+(T)	-( )	1(T)	1(T)	+(T)	
431 BALSAG	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
442 CHIUMB	-( )	1(4)	-( )	2(T)	5(3)	4(T)	6(2)	6(1)	7(3)	10(12)	8(1)	6(5)	
445 CIRALP	6(3)	6(10)	9(22)	5(18)	1(T)	-( )	-( )	1(7)	-( )	-( )	-( )	-( )	
447 CLIUNI	10(6)	9(6)	10(7)	10(5)	10(4)	10(7)	10(7)	10(6)	10(6)	10(16)	10(8)	9(6)	
449 COPOCC	4(6)	8(18)	10(7)	10(15)	10(28)	10(11)	10(21)	9(22)	10(13)	10(32)	9(20)	9(18)	
452 CORCAN	3(2)	4(6)	9(5)	8(3)	2(10)	4(T)	4(23)	5(7)	4(2)	6(4)	3(5)	4(6)	
454 DISHOO	9(4)	8(9)	8(4)	7(7)	9(3)	9(T)	7(3)	7(6)	4(T)	2(T)	1(T)	6(4)	
455 DISTRA	-( )	-( )	1(38)	1(13)	1(T)	-( )	-( )	1(21)	-( )	-( )	-( )	1(3)	
458 DODJEF	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
465 FRAVES	-( )	+(T)	-( )	1(T)	1(3)	-( )	-( )	2(T)	4(T)	-( )	-( )	2(T)	
467 FRAGAR	1(T)	+(T)	2(T)	1(1)	-( )	-( )	-( )	1(1)	-( )	-( )	1(T)	1(1)	
466 FRAVIR	-( )	1(T)	2(3)	1(T)	1(T)	-( )	-( )	2(5)	-( )	-( )	-( )	1(1)	
471 GALTRI	7(2)	9(3)	10(5)	10(2)	9(T)	10(T)	7(3)	7(1)	6(T)	1(T)	3(T)	6(1)	
476 GOOOBL	5(T)	5(T)	4(T)	8(T)	7(T)	7(T)	10(T)	8(T)	7(1)	6(1)	10(T)	7(T)	
482 HEUCYL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	
489 LIGCAN	-( )	1(3)	-( )	-( )	1(T)	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	
800 LIGVER	-( )	+(T)	-( )	1(T)	-( )	-( )	-( )	+(T)	1(T)	-( )	1(T)	1(1)	
647 MERPAN	1(T)	3(1)	2(1)	-( )	2(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	
501 MITBRE	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
649 MITPEN	1(19)	2(12)	2(3)	1(T)	-( )	-( )	1(T)	+(T)	-( )	-( )	-( )	-( )	
502 MITSTA	1(3)	2(T)	2(2)	3(T)	3(T)	3(T)	2(2)	3(T)	3(T)	1(T)	3(1)	3(T)	
505 OSMCHI	8(T)	7(T)	8(2)	7(1)	3(T)	4(T)	4(T)	5(T)	3(T)	2(T)	3(T)	6(T)	
507 PEDBRA	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	+(T)	2(T)	-( )	1(T)	-( )	
508 PEDCON	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	
509 PEDRAC	-( )	+(T)	-( )	-( )	1(T)	3(T)	1(T)	2(2)	2(T)	6(T)	6(1)	2(T)	
519 POLPUL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	
526 PYRASA	1(T)	1(T)	2(T)	1(T)	6(T)	4(T)	5(T)	3(T)	7(T)	5(2)	7(T)	3(T)	
529 PYRSEC	1(T)	1(T)	-( )	1(T)	5(T)	4(T)	7(1)	5(1)	7(T)	6(4)	6(T)	4(T)	
539 SENTRI	4(3)	6(3)	8(8)	2(T)	4(T)	6(T)	1(T)	1(T)	-( )	-( )	2(2)	-( )	
542 SMIRAC	1(T)	1(T)	2(T)	1(T)	2(T)	6(T)	5(T)	3(T)	2(T)	1(T)	1(T)	1(1)	
543 SMISTE	8(3)	9(7)	9(8)	9(5)	9(4)	10(6)	10(8)	9(5)	8(1)	7(4)	6(4)	9(4)	
546 STRAMP	8(1)	6(2)	6(T)	4(T)	3(T)	3(T)	-( )	1(T)	1(T)	2(T)	-( )	+(T)	
810 SYNPLA	-( )	-( )	1(T)	1(T)	1(3)	-( )	4(5)	1(2)	-( )	1(T)	-( )	1(T)	
547 THAOCC	2(T)	5(T)	2(2)	4(2)	4(1)	10(T)	2(T)	7(1)	4(T)	4(T)	3(2)	5(T)	
548 TIATRI	9(17)	10(15)	10(5)	9(5)	10(4)	9(3)	10(4)	8(3)	9(T)	9(2)	6(1)	4(2)	
563 TRACAR	4(3)	5(7)	7(15)	2(T)	2(T)	1(T)	2(T)	1(3)	1(T)	1(T)	1(T)	-( )	
560 TRIOVA	9(T)	9(2)	8(T)	8(T)	9(T)	9(T)	10(2)	7(T)	6(T)	9(1)	7(1)	7(T)	
551 VALSIT	-( )	1(T)	-( )	-( )	-( )	1(T)	-( )	+(T)	-( )	-( )	2(T)	-( )	
552 VERVIR	3(3)	5(T)	2(T)	1(T)	2(T)	3(T)	2(T)	1(T)	-( )	2(T)	1(T)	+(T)	
554 VIOADU	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	
556 VIOGLA	7(3)	5(6)	8(2)	3(2)	1(T)	3(T)	4(1)	2(T)	-( )	-( )	-( )	1(T)	
557 VIOORB	7(4)	6(4)	8(3)	9(2)	6(1)	7(1)	10(2)	8(2)	9(T)	9(1)	9(T)	7(2)	
558 XERTEN	1(T)	+(T)	-( )	+(T)	2(T)	6(T)	5(T)	3(2)	7(9)	10(12)	10(12)	2(2)	

CODE TO CONSTANCY VALUES

+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

(con.)

SERIES H.T. PHASE	TSME STAM MEFE	TSME STAM LUHI	TSME CLUN MEFE	TSME CLUN XETE	TSME MEFE XETE	TSME MEFE LUHI	TSME XETE VAGL	TSME XETE VASC	TSME XETE LUHI	ABLA CACA LEGL	ABLA CACA VACA	ABLA CACA CACA	
NO. OF PLOTS	N= 4	N= 4	N= 23	N= 8	N= 15	N= 14	N= 15	N= 12	N= 11	N= 9	N= 4	N= 6	N=
TREE SPECIES													
1 ABIGRA	-( )	-( )	3(24)	1(15)	1(T)	-( )	1(T)	2(T)	-( )	3(T)	7(T)	-( )	
2 ABILAS	10(44)	10(51)	10(24)	7(13)	10(41)	10(33)	10(22)	10(29)	10(33)	10(29)	10(5)	10(23)	
3 BETPAP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
6 LAROCC	5(3)	-( )	6(4)	7(16)	1(15)	1(19)	5(11)	2(1)	-( )	3(T)	-( )	-( )	
7 PICENG	10(44)	2(63)	10(28)	9(16)	7(28)	6(22)	7(3)	9(7)	5(7)	10(28)	10(8)	10(23)	
9 PINALB	-( )	-( )	+(3)	-( )	1(3)	4(T)	2(18)	4(2)	5(4)	2(T)	-( )	2(T)	
10 PINCON	-( )	-( )	4(23)	7(32)	5(20)	5(17)	7(34)	9(45)	4(14)	9(21)	10(50)	7(12)	
12 PINMON	5(9)	-( )	6(6)	6(7)	3(4)	1(2)	5(6)	2(2)	1(T)	1(T)	-( )	-( )	
13 PINPON	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
16 PSEMEN	5(15)	-( )	6(8)	7(8)	1(8)	-( )	5(16)	3(14)	-( )	4(T)	-( )	3(19)	
17 THUPLI	-( )	-( )	2(T)	1(T)	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
18 TSUHET	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
19 TSUMER	10(14)	10(65)	10(32)	10(21)	10(37)	10(49)	10(30)	10(29)	10(56)	-( )	-( )	-( )	
SHRUB SPECIES													
102 ACEGLA	-( )	-( )	2(5)	1(15)	-( )	-( )	1(2)	-( )	-( )	-( )	-( )	-( )	
104 ALNSIN	5(8)	2(38)	5(8)	1(T)	1(T)	-( )	1(T)	-( )	-( )	2(15)	-( )	7(11)	
105 AMEALN	-( )	-( )	1(T)	2(2)	-( )	-( )	1(T)	-( )	-( )	-( )	2(T)	3(8)	
110 CRADOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
111 HOLDIS	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
113 LEDGLA	2(T)	-( )	-( )	-( )	1(9)	1(T)	-( )	-( )	-( )	10(44)	10(17)	3(2)	
115 LONUTA	7(1)	5(8)	7(3)	9(4)	4(3)	1(T)	3(2)	1(T)	3(5)	3(T)	2(3)	5(T)	
116 MENFER	10(61)	10(44)	10(54)	4(2)	10(53)	10(54)	4(T)	2(2)	2(T)	6(33)	-( )	5(13)	
117 OPLHOR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
118 PACMYR	-( )	-( )	2(3)	5(5)	1(2)	-( )	2(7)	-( )	-( )	-( )	-( )	-( )	
119 PHILEW	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
122 PHYMAL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
124 PRUVIR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
127 RHOALB	-( )	-( )	+(T)	-( )	1(3)	2(18)	-( )	-( )	-( )	-( )	-( )	-( )	
130 RIBLAC	2(T)	2(T)	3(3)	2(T)	1(T)	-( )	1(T)	-( )	-( )	1(3)	-( )	5(T)	
133 ROSGYM	-( )	-( )	2(2)	2(2)	-( )	-( )	1(3)	-( )	-( )	1(T)	-( )	-( )	
161 ROSNUT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
134 ROSWOO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
136 RUBPAR	2(3)	-( )	3(T)	2(8)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
137 SALSCO	-( )	-( )	1(2)	1(3)	1(T)	1(T)	1(T)	1(T)	-( )	-( )	-( )	-( )	
142 SPIBET	2(3)	-( )	1(1)	2(3)	-( )	-( )	3(1)	2(T)	-( )	2(T)	-( )	2(T)	
143 SYMALB	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	3(T)	
144 TAXBRE	-( )	-( )	+(T)	-( )	1(19)	-( )	-( )	-( )	-( )	-( )	-( )	2(3)	
146 VACGLO	10(33)	5(33)	7(37)	7(58)	5(41)	7(31)	8(50)	10(34)	5(17)	6(22)	2(T)	7(10)	
194 VACMEM	-( )	5(9)	4(19)	2(8)	3(24)	1(9)	3(38)	-( )	3(18)	-( )	-( )	-( )	
LOW WOODY PLANTS AND DWARF SHRUBS													
201 ARCUVA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
203 BERREP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
205 GAUHUM	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	9(3)	5(T)	-( )	
206 LINBOR	-( )	-( )	+(T)	1(15)	-( )	-( )	-( )	-( )	-( )	2(9)	5(T)	5(1)	
219 PHYEMP	-( )	2(15)	+(T)	-( )	2(T)	4(10)	-( )	2(T)	6(23)	-( )	-( )	-( )	
218 SATDOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
145 VACCAE	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	10(30)	3(T)	
147 VACMYR	-( )	-( )	+(T)	-( )	-( )	1(15)	-( )	-( )	1(15)	-( )	-( )	2(T)	
148 VACSCO	-( )	7(2)	1(T)	2(T)	7(16)	9(15)	5(1)	10(29)	9(25)	10(27)	10(20)	8(3)	
FERNS AND ALLIED TAXA													
260 ADIPED	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
251 ATHFIL	5(T)	2(3)	2(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	3(2)	
255 GYMDRY	5(T)	-( )	1(8)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
258 POLMUN	2(T)	-( )	1(T)	1(T)	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
259 PTEAQU	-( )	-( )	2(1)	4(6)	1(T)	2(T)	1(2)	-( )	-( )	-( )	-( )	2(3)	
GRAMINOIDS													
301 AGRSPI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
304 BROVUL	5(T)	2(T)	6(T)	5(1)	-( )	1(T)	1(T)	-( )	-( )	2(T)	-( )	3(T)	
305 CALCAN	-( )	5(8)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	3(1)	10(13)	10(27)	
307 CALRUB	-( )	-( )	+(3)	4(6)	1(T)	1(15)	3(10)	2(1)	-( )	3(T)	2(T)	-( )	
309 CARGEY	-( )	2(T)	2(T)	5(1)	2(1)	4(T)	4(10)	7(1)	5(4)	2(T)	2(T)	2(T)	
311 CARROS	-( )	-( )	+(T)	1(T)	1(T)	1(T)	1(T)	4(1)	2(T)	-( )	-( )	2(T)	
317 FESIDA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
325 LUZHIT	7(T)	10(24)	1(T)	-( )	3(T)	9(10)	2(T)	4(T)	8(17)	-( )	-( )	2(T)	

(con.)

APPENDIX C (Con.)

SERIES H.T. PHASE	TSME STAM MEFE	TSME STAM LUHI	TSME CLUN MEFE	TSME CLUN XETE	TSME MEFE XETE	TSME MEFE LUHI	TSME XETE VAGL	TSME XETE VASC	TSME XETE LUHI	ABLA CACA LEGL	ABLA CACA VACA	ABLA CACA CACA	
NO. OF PLOTS	N= 4	N= 4	N= 23	N= 8	N= 15	N= 14	N= 15	N= 12	N= 11	N= 9	N= 4	N= 6	N=
PERENNIAL FORBS													
401 ACHMIL	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	5(T)	-( )	
402 ACTRUB	2(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
403 ADEBIC	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
407 ANEPIP	5(T)	2(T)	7(T)	9(T)	1(T)	1(T)	1(T)	1(T)	1(3)	6(T)	5(T)	3(T)	
418 ARANUD	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
420 AREMAC	2(T)	-( )	+(T)	1(T)	-( )	1(T)	-( )	-( )	-( )	1(T)	-( )	2(3)	
421 ARNCOR	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
422 ARNLAT	10(21)	7(11)	6(24)	5(10)	4(12)	4(10)	1(2)	-( )	5(T)	4(14)	-( )	5(2)	
564 ASACAU	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	
426 ASTCON	-( )	-( )	+(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
431 BALSAG	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
442 CHIUMB	-( )	-( )	4(1)	7(T)	3(T)	1(T)	6(T)	4(2)	1(T)	3(T)	5(T)	-( )	
445 CIRALP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
447 CLIUNI	10(9)	-( )	9(3)	9(3)	1(T)	1(T)	1(T)	-( )	-( )	2(T)	5(T)	5(5)	
449 COPOCC	7(2)	-( )	5(11)	4(7)	1(T)	-( )	1(T)	-( )	-( )	7(6)	5(2)	5(T)	
452 CORCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(3)	
454 DISHOO	-( )	-( )	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	
455 DISTRA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
458 DODJEF	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	4(5)	-( )	7(1)	
465 FRAVES	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	3(T)	
467 FRAGAR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
466 FRAVIR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	5(T)	2(T)	
471 GALTRI	5(T)	-( )	4(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	5(T)	
476 GOOOBL	5(T)	2(T)	7(T)	5(1)	5(T)	3(T)	5(T)	2(T)	2(T)	3(T)	-( )	-( )	
482 HEUCYL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
489 LIGCAN	-( )	5(3)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(2)	7(2)	5(18)	
800 LIGVER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	
647 MERPAN	2(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	2(T)	
501 MITBRE	7(T)	5(2)	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
649 MITPEN	-( )	5(8)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	5(T)	3(T)	
502 MITSTA	-( )	-( )	2(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
505 OSMCHI	-( )	-( )	1(T)	4(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
507 PEDBRA	2(T)	2(T)	3(T)	1(T)	2(T)	4(T)	3(T)	3(T)	2(T)	-( )	2(T)	-( )	
508 PEDCON	2(T)	2(T)	1(2)	-( )	1(T)	1(T)	2(T)	2(3)	2(2)	-( )	-( )	-( )	
509 PEDRAC	-( )	-( )	3(T)	1(T)	2(T)	2(T)	3(T)	2(T)	1(3)	2(T)	-( )	3(T)	
519 POLPUL	-( )	10(1)	1(T)	-( )	1(2)	4(T)	1(T)	-( )	2(2)	-( )	7(T)	-( )	
526 PYRASA	5(2)	-( )	5(T)	5(1)	4(T)	1(T)	3(T)	2(T)	-( )	3(1)	5(T)	-( )	
529 PYRSEC	2(T)	2(T)	7(1)	10(T)	5(1)	2(1)	5(T)	3(T)	2(2)	3(1)	-( )	2(T)	
539 SENTRI	7(2)	5(T)	2(T)	1(T)	-( )	1(T)	1(T)	-( )	1(T)	3(5)	7(T)	8(4)	
542 SMIRAC	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
543 SMISTE	5(2)	-( )	4(T)	6(2)	-( )	-( )	1(T)	-( )	-( )	-( )	2(T)	5(1)	
546 STRAMP	5(T)	2(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	1(3)	2(T)	5(T)	
810 SYNPLA	-( )	-( )	1(5)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
547 THAOCC	5(T)	-( )	4(T)	2(2)	1(T)	-( )	1(T)	-( )	-( )	3(T)	2(15)	7(1)	
548 TIATRI	10(5)	2(T)	5(1)	2(T)	1(T)	-( )	1(T)	-( )	-( )	2(T)	2(T)	2(T)	
563 TRACAR	2(T)	2(38)	-( )	-( )	-( )	1(T)	1(T)	-( )	-( )	1(15)	2(T)	8(4)	
560 TRIOVA	10(T)	5(T)	7(T)	5(T)	1(T)	-( )	2(T)	-( )	-( )	4(T)	7(T)	7(T)	
551 VALSIT	2(T)	2(T)	1(T)	-( )	1(T)	1(T)	-( )	-( )	1(T)	2(T)	5(8)	2(T)	
552 VERVIR	5(T)	5(3)	1(T)	-( )	-( )	4(T)	-( )	-( )	1(T)	2(T)	-( )	5(2)	
554 VIOADU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
556 VIOGLA	10(2)	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	5(T)	
557 VIOORB	7(1)	2(3)	9(T)	10(3)	5(1)	3(T)	4(T)	2(T)	3(1)	8(1)	7(6)	2(T)	
558 XERTEN	7(2)	7(T)	8(26)	10(46)	10(34)	10(29)	10(61)	10(50)	10(51)	8(18)	7(15)	7(10)	

CODE TO CONSTANCY VALUES

+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

(con.)

	ABLA STAM MEFE	ABLA STAM LICA	ABLA CLUN MEFE	ABLA CLUN XETE	ABLA CLUN CLUN	ABLA MEFE LUHI	ABLA MEFE VASC	ABLA MEFE COOC	ABLA MEFE XETE	ABLA XETE LUHI	ABLA XETE VASC	ABLA XETE COOC	ABLA XETE VAGL	ABLA LUHI
NO. OF PLOTS	N= 17	N= 14	N= 17	N= 18	N= 3	N= 8	N= 11	N= 10	N= 6	N= 18	N= 20	N= 16	N= 16	N= 16
TREE SPECIES														
1 ABIGRA	2(30)	4(14)	4(21)	5(23)	7(20)	-( )	4(4)	3(2)	2(T)	-( )	2(3)	7(11)	2(14)	-( )
2 ABILAS	10(60)	10(26)	10(40)	9(45)	10(54)	10(72)	9(82)	10(35)	10(60)	10(52)	10(30)	10(33)	10(37)	10(48)
3 BETPAP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
6 LAROCC	1(2)	1(3)	1(8)	5(23)	7(19)	-( )	-( )	1(38)	-( )	-( )	-( )	2(5)	2(4)	-( )
7 PICENG	9(44)	10(45)	10(36)	8(12)	10(54)	9(21)	8(12)	10(24)	8(17)	7(4)	7(8)	9(19)	6(5)	5(18)
9 PINALB	-( )	-( )	-( )	-( )	-( )	6(1)	5(T)	-( )	-( )	10(19)	3(4)	1(T)	3(14)	10(30)
10 PINCON	2(3)	4(17)	4(7)	3(28)	7(26)	2(8)	8(10)	7(9)	3(33)	7(23)	9(57)	10(33)	7(38)	-( )
12 PINMON	1(8)	-( )	2(1)	3(25)	-( )	1(T)	-( )	1(T)	2(15)	-( )	-( )	1(T)	2(8)	-( )
13 PINPON	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )
16 PSEMEN	2(10)	2(10)	4(21)	8(20)	7(8)	-( )	3(2)	6(7)	2(T)	-( )	3(3)	7(18)	7(24)	-( )
17 THUPLI	1(T)	1(T)	1(T)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
18 TSUHET	-( )	1(T)	-( )	2(1)	3(T)	-( )	-( )	-( )	2(T)	-( )	-( )	-( )	-( )	-( )
19 TSUMER	1(T)	-( )	-( )	1(T)	-( )	-( )	-( )	1(T)	2(T)	-( )	-( )	-( )	1(T)	-( )
SHRUB SPECIES														
102 ACEGLA	3(4)	1(2)	2(1)	4(5)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(3)	-( )
104 ALNSIN	4(5)	4(1)	4(22)	3(4)	10(1)	1(T)	1(63)	3(T)	2(3)	-( )	2(T)	4(10)	-( )	-( )
105 AMEALN	1(T)	1(T)	3(T)	4(1)	7(2)	1(T)	-( )	1(T)	-( )	-( )	-( )	1(T)	3(T)	-( )
110 CRADOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
111 HOLDIS	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
113 LEDGLA	1(3)	1(2)	1(3)	-( )	-( )	-( )	-( )	4(1)	2(T)	1(T)	1(T)	1(T)	-( )	-( )
115 LONUTA	5(5)	5(T)	8(1)	9(2)	7(T)	5(4)	4(1)	5(T)	2(15)	4(2)	2(T)	7(T)	5(T)	2(T)
116 MENFER	10(47)	7(2)	10(48)	6(1)	7(2)	9(48)	9(58)	10(36)	10(55)	2(1)	2(1)	4(T)	1(2)	2(3)
117 OPLHOR	1(2)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
118 PACMYR	1(2)	1(T)	1(T)	5(4)	3(T)	-( )	-( )	1(3)	2(3)	-( )	-( )	1(T)	2(7)	-( )
119 PHLEW	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
122 PHYMAL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
124 PRUVIR	-( )	-( )	-( )	-( )	3(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
127 RHOALB	4(12)	-( )	-( )	1(T)	-( )	7(22)	-( )	-( )	3(32)	-( )	-( )	-( )	-( )	-( )
130 RIBLAC	8(1)	5(3)	6(2)	3(T)	3(T)	-( )	-( )	2(T)	-( )	1(T)	-( )	1(T)	-( )	-( )
133 ROSGYM	1(T)	-( )	1(T)	5(3)	7(T)	-( )	-( )	2(T)	-( )	-( )	1(T)	2(1)	1(2)	-( )
161 ROSNUT	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
134 ROSWOO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
136 RUBPAR	4(3)	3(2)	2(T)	6(2)	7(8)	-( )	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )
137 SALSCO	-( )	1(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	1(T)	1(2)	1(T)	1(T)	-( )
142 SPIBET	-( )	1(3)	1(T)	5(1)	3(T)	-( )	-( )	1(T)	-( )	-( )	4(1)	5(3)	6(1)	-( )
143 SYMALB	1(T)	4(2)	1(T)	1(T)	3(15)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
144 TAXBRE	1(2)	1(3)	1(8)	1(38)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )
146 VACGLO	7(15)	9(8)	8(22)	8(49)	10(25)	7(28)	7(23)	10(36)	3(63)	6(10)	6(25)	9(52)	7(47)	3(9)
194 VACMEM	3(24)	-( )	2(33)	2(35)	-( )	2(15)	2(15)	-( )	7(23)	1(50)	+(15)	-( )	2(35)	-( )
LOW WOODY PLANTS AND DWARF SHRUBS														
201 ARCUVA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(1)	-( )	1(T)	-( )
203 BERREP	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	1(T)	-( )
205 GALHUM	1(T)	1(T)	1(T)	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	+(T)	1(2)	-( )	-( )
206 LINBOR	1(T)	4(4)	2(7)	1(33)	7(19)	-( )	-( )	4(10)	-( )	-( )	1(1)	6(12)	1(T)	-( )
219 PHYEMP	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )
218 SATDOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
145 VACCAE	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(3)	1(18)	1(3)	1(15)	-( )
147 VACMYR	1(T)	-( )	-( )	1(T)	-( )	2(2)	-( )	-( )	-( )	1(19)	-( )	1(T)	-( )	-( )
148 VACSCO	1(2)	4(13)	5(9)	1(3)	3(T)	7(12)	9(11)	7(13)	5(T)	8(49)	10(50)	7(25)	6(1)	5(18)
FERNS AND ALLIED TAXA														
260 ADIPED	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
251 ATHFIL	5(5)	4(15)	-( )	-( )	3(T)	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )
255 GYMDRY	2(41)	1(8)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
258 POLMUN	1(T)	1(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )
259 PTEAQU	2(1)	-( )	1(T)	3(2)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
GRAMINOIDS														
301 AGRSPI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )
304 BROVUL	5(2)	8(T)	7(T)	7(2)	7(T)	-( )	-( )	3(T)	-( )	1(T)	+(T)	2(1)	1(2)	-( )
305 CALCAN	1(3)	1(15)	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	+(T)	1(T)	-( )	-( )
307 CALRUB	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	3(T)	-( )	-( )	5(5)	4(1)	5(12)	-( )
309 CARGEY	-( )	-( )	-( )	4(1)	-( )	-( )	2(T)	-( )	-( )	3(1)	4(4)	2(1)	6(11)	-( )
311 CARROS	1(T)	1(T)	1(T)	2(1)	-( )	1(T)	1(T)	-( )	-( )	1(T)	1(T)	1(T)	2(T)	2(T)
317 FESIDA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )
325 LUZHIT	5(T)	1(2)	1(T)	-( )	-( )	10(6)	4(T)	1(T)	5(T)	10(11)	1(T)	-( )	1(T)	10(54)

(con.)

APPENDIX C (Con.)

	ABLA STAM MEFE	ABLA STAM LICA	ABLA CLUN MEFE	ABLA CLUN XETE	ABLA CLUN CLUN	ABLA MEFE LUHI	ABLA MEFE VASC	ABLA MEFE COOC	ABLA MEFE XETE	ABLA XETE LUHI	ABLA XETE VASC	ABLA XETE COOC	ABLA XETE VAGL	ABLA LUHI
NO. OF PLOTS	N= 17	N= 14	N= 17	N= 18	N= 3	N= 8	N= 11	N= 10	N= 6	N= 18	N= 20	N= 16	N= 16	N= 16
PERENNIAL FORBS														
401 ACHMIL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	1(T)	3(T)
402 ACTRUB	3(5)	5(T)	1(T)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )
403 ADEBIC	1(T)	-( )	-( )	3(T)	3(T)	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )
407 ANEPIP	4(5)	4(T)	8(2)	7(2)	7(T)	-( )	6(T)	10(T)	3(2)	-( )	6(T)	9(T)	4(T)	-( )
418 ARANUD	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
420 AREMAC	2(6)	2(T)	2(1)	4(T)	3(3)	-( )	1(T)	1(T)	-( )	-( )	+(T)	4(T)	1(T)	-( )
421 ARNCOR	1(8)	-( )	1(15)	-( )	-( )	-( )	1(T)	2(T)	2(T)	-( )	1(T)	2(5)	-( )	-( )
422 ARNLAT	6(21)	8(10)	7(33)	3(27)	3(85)	2(8)	4(1)	5(19)	3(T)	4(3)	3(T)	2(8)	3(T)	5(5)
564 ASACAU	3(2)	3(2)	1(T)	2(1)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
426 ASTCON	-( )	-( )	-( )	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )
431 BALSAG	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
442 CHIUMB	2(1)	1(T)	5(T)	6(1)	7(2)	4(T)	4(T)	9(T)	2(T)	1(T)	5(2)	10(T)	6(1)	-( )
445 CIRALP	1(T)	1(2)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
447 CLIUNI	8(9)	6(3)	9(6)	9(8)	10(1)	-( )	-( )	4(T)	-( )	-( )	-( )	1(T)	1(T)	-( )
449 COPOCC	4(9)	6(14)	5(11)	5(7)	7(9)	-( )	-( )	10(7)	2(T)	-( )	1(2)	10(4)	1(T)	-( )
452 CORCAN	1(3)	1(8)	1(8)	-( )	3(15)	-( )	-( )	3(3)	-( )	-( )	-( )	1(1)	-( )	-( )
454 DISHOO	2(1)	1(T)	1(T)	2(13)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
455 DISTRA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
458 DODJEF	1(T)	3(4)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
465 FRAVES	1(T)	3(T)	-( )	2(1)	-( )	-( )	-( )	3(T)	-( )	-( )	1(T)	-( )	-( )	-( )
467 FRAGAR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
466 FRAVIR	1(T)	-( )	1(T)	1(2)	3(T)	-( )	-( )	1(1)	-( )	-( )	1(2)	1(T)	1(T)	-( )
471 GALTRI	5(1)	6(3)	5(T)	6(T)	7(T)	-( )	-( )	1(T)	-( )	-( )	-( )	1(T)	1(T)	-( )
476 GOOOBL	7(T)	1(T)	10(T)	7(T)	10(T)	2(T)	6(T)	8(1)	5(T)	1(T)	4(T)	6(T)	4(T)	3(T)
482 HEUCYL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
489 LIGCAN	4(2)	5(3)	1(T)	-( )	-( )	-( )	-( )	1(T)	-( )	1(T)	-( )	-( )	-( )	-( )
800 LIGVER	1(2)	1(T)	1(T)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )
647 MERPAN	1(T)	1(3)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
501 MITBRE	2(2)	1(8)	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	-( )	-( )	-( )	-( )	2(T)
649 MITPEN	4(2)	2(1)	1(T)	-( )	-( )	2(1)	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )
502 MITSTA	2(2)	1(T)	2(T)	6(T)	3(T)	1(T)	-( )	1(T)	-( )	-( )	-( )	1(8)	1(T)	-( )
505 OSMCHI	5(1)	5(T)	4(T)	5(1)	7(T)	-( )	-( )	-( )	-( )	1(T)	-( )	1(T)	1(T)	-( )
507 PEDBRA	5(T)	1(T)	2(T)	1(T)	-( )	2(T)	5(2)	1(T)	-( )	1(T)	+(T)	-( )	2(T)	-( )
508 PEDCON	1(T)	1(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	1(T)	+(T)	-( )	-( )	3(2)
509 PEDRAC	3(1)	2(T)	7(T)	5(T)	3(T)	2(T)	5(T)	7(T)	2(3)	1(2)	3(T)	6(T)	1(T)	2(T)
519 POLPUL	2(T)	4(2)	2(1)	1(T)	3(T)	-( )	1(T)	1(T)	-( )	1(T)	+(T)	1(T)	1(T)	5(T)
526 PYRASA	1(T)	1(T)	4(T)	3(T)	7(2)	-( )	-( )	8(T)	2(T)	-( )	1(T)	1(T)	-( )	-( )
529 PYRSEC	6(1)	4(T)	7(1)	6(T)	7(2)	4(T)	4(1)	7(T)	8(T)	1(T)	2(T)	6(T)	3(T)	-( )
539 SENTRI	6(5)	9(6)	1(T)	-( )	-( )	1(T)	-( )	1(T)	-( )	1(T)	+(T)	-( )	-( )	-( )
542 SMIRAC	1(T)	-( )	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
543 SMISTE	5(3)	6(1)	4(T)	7(2)	10(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )
546 STRAMP	5(T)	4(T)	-( )	-( )	3(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
810 SYNPLA	1(T)	1(26)	1(9)	2(2)	-( )	-( )	1(T)	-( )	-( )	-( )	+(T)	-( )	-( )	-( )
547 THAOCC	7(4)	6(2)	8(1)	8(1)	10(5)	-( )	-( )	2(T)	-( )	-( )	+(T)	1(T)	3(T)	-( )
548 TIATRI	7(17)	7(8)	5(8)	4(T)	7(2)	-( )	-( )	2(T)	-( )	1(T)	-( )	1(T)	1(T)	-( )
563 TRACAR	4(7)	5(19)	-( )	-( )	3(T)	1(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	2(T)
560 TRIOVA	6(2)	7(T)	9(T)	7(T)	3(T)	1(T)	1(T)	6(T)	-( )	1(T)	-( )	3(T)	2(T)	2(T)
551 VALSIT	4(3)	4(T)	3(T)	3(2)	-( )	1(T)	2(T)	1(T)	-( )	2(T)	+(T)	1(T)	1(T)	3(9)
552 VERVIR	5(3)	5(2)	2(1)	1(T)	-( )	1(T)	-( )	1(T)	3(T)	2(T)	+(T)	-( )	-( )	2(T)
554 VIOADU	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
556 VIOGLA	2(1)	4(11)	1(T)	1(T)	3(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )
557 VIOORB	8(4)	4(2)	8(3)	8(2)	10(T)	2(T)	7(T)	10(T)	7(T)	1(T)	6(T)	9(2)	4(T)	2(3)
558 XERTEN	6(13)	7(5)	10 (23)	10 (41)	-( )	10(36)	9(34)	10(21)	8(48)	10(59)	10(36)	10(32)	10(51)	5(T)

CODE TO CONSTANCY VALUES

+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

(con.)

APPENDIX C (Con.)

SERIES	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR	ABGR
H.T.	SETR	ASCA	ASCA	ASCA	CLUN	CLUN	CLUN	CLUN	CLUN	LIBO	LIBO	XETE	XETE
PHASE		MEFE	TABR	ASCA	MEFE	TABR	XETE	PHMA	CLUN	LIBO	XETE	COOC	VAGL
NO. OF PLOTS	N= 9	N= 12	N= 21	N= 32	N= 17	N= 11	N= 38	N= 21	N= 27	N= 11	N= 7	N= 15	N= 16
TREE SPECIES													
1 ABIGRA	9(26)	10(46)	10(43)	10(45)	10(43)	10(33)	10(42)	10(30)	10(62)	10(40)	10(39)	10(50)	10(25)
2 ABILAS	3(2)	2(11)	1(5)	1(2)	4(3)	3(2)	3(2)	+(3)	1(1)	2(19)	4(6)	5(3)	6(5)
3 BETPAP	-( )	-( )	-( )	+(15)	-( )	-( )	-( )	+(3)	-( )	-( )	-( )	-( )	( )
6 LAROCC	3(6)	2(2)	3(3)	4(5)	4(9)	3(3)	4(18)	3(21)	3(7)	3(2)	6(10)	4(14)	2(8)
7 PICENG	8(11)	8(13)	8(7)	2(12)	8(7)	5(8)	6(6)	-( )	2(6)	5(6)	6(11)	3(11)	2(5)
9 PINALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
10 PINCON	-( )	2(15)	-( )	1(23)	5(18)	1(3)	6(17)	3(4)	3(21)	5(15)	9(43)	6(17)	9(38)
12 PINMON	-( )	1(3)	-( )	2(7)	1(3)	-( )	2(5)	4(3)	3(7)	1(T)	1(T)	-( )	1(1)
13 PINPON	-( )	2(T)	-( )	2(11)	1(T)	-( )	3(3)	7(15)	4(6)	6(14)	4(14)	3(17)	4(12)
16 PSEMEN	2(8)	5(21)	4(8)	9(40)	6(11)	7(8)	9(28)	10(49)	9(26)	8(31)	9(38)	10(23)	9(18)
17 THUPLI	-( )	1(T)	+(T)	2(T)	1(3)	-( )	1(2)	-( )	1(2)	-( )	-( )	1(T)	( )
18 TSUHET	-( )	-( )	-( )	'(T)	-( )	-( )	1(T)	-( )	1(8)	-( )	-( )	-( )	( )
19 TSUMER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
SHRUB SPECIES													
102 ACEGLA	8(8)	9(12)	9(11)	9(6)	2(11)	5(7)	4(4)	9(8)	6(7)	5(2)	1(3)	3(T)	1(2)
104 ALNSIN	1(3)	3(4)	-( )	+(T)	2(2)	-( )	2(3)	+(T)	1(T)	-( )	1(T)	1(8)	2(1)
105 AMEALN	4(6)	7(2)	4(1)	6(2)	5(3)	4(2)	7(2)	9(3)	9(2)	6(T)	7(2)	4(7)	6(1)
110 CRADOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	1(T)	-( )	-( )	( )
111 HOLDIS	-( )	-( )	-( )	5(1)	1(T)	1(3)	1(2)	8(14)	4(2)	3(1)	3(9)	2(1)	1(1)
113 LEDGLA	1(3)	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
115 LONUTA	8(2)	8(2)	6(T)	7(1)	6(4)	10(T)	7(1)	3(T)	6(2)	6(T)	7(4)	5(2)	2(1)
116 MENFER	8(14)	10(23)	6(2)	1(2)	10(23)	3(2)	3(2)	-( )	1(T)	1(T)	4(1)	3(2)	1(1)
117 OPLHOR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
118 PACMYR	3(T)	4(T)	2(T)	4(7)	4(10)	2(2)	4(12)	4(9)	2(12)	-( )	4(5)	2(T)	2(4)
119 PHILEW	-( )	-( )	-( )	1(T)	-( )	1(3)	-( )	2(5)	1(6)	1(T)	-( )	-( )	( )
122 PHYMAL	-( )	2(T)	-( )	4(7)	1(T)	-( )	1(6)	8(21)	3(3)	2(T)	3(9)	3(10)	1(1)
124 PRUVIR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	1(T)	-( )	-( )	( )
127 RHOALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
130 RIBLAC	7(2)	6(T)	3(T)	2(T)	1(2)	4(1)	1(T)	-( )	2(6)	1(T)	1(T)	1(T)	( )
133 ROSGYM	6(2)	8(2)	6(1)	9(4)	8(3)	8(2)	9(2)	10(7)	10(5)	9(3)	7(3)	9(1)	7(2)
161 ROSNUT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	( )
134 ROSWOO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(15)	-( )	-( )	-( )	-( )	( )
136 RUBPAR	6(1)	7(T)	3(T)	7(6)	3(T)	3(T)	5(6)	7(7)	6(10)	4(T)	4(T)	6(1)	2(T)
137 SALSCO	1(3)	-( )	-( )	1(T)	1(T)	-( )	1(1)	-( )	-( )	-( )	-( )	1(T)	2(1)
142 SPIBET	2(T)	1(T)	2(T)	5(T)	2(1)	3(T)	7(4)	8(5)	6(8)	5(T)	7(4)	7(7)	8(2)
143 SYMALB	2(T)	3(2)	5(T)	8(6)	2(1)	3(T)	3(2)	10(17)	8(5)	7(10)	1(T)	3(5)	1(1)
144 TAXBRE	7(32)	7(32)	10(56)	1(T)	6(28)	10(72)	2(2)	-( )	3(5)	1(T)	1(3)	1(T)	1(1)
146 VACGLO	1(T)	5(16)	5(2)	5(8)	5(17)	1(3)	9(29)	5(3)	6(12)	5(1)	9(43)	10(29)	10(37)
194 VACMEM	7(26)	6(7)	3(8)	1(15)	5(16)	8(5)	1(23)	-( )	1(1)	-( )	-( )	-( )	( )
LOW WOODY PLANTS AND DWARF SHRUBS													
201 ARCUVA	-( )	-( )	-( )	+(T)	1(T)	-( )	1(T)	+(3)	1(6)	3(T)	-( )	-( )	2(5)
203 BERREP	-( )	1(T)	-( )	2(1)	2(T)	1(3)	5(T)	8(7)	5(2)	6(4)	4(T)	3(4)	6(1)
205 GAUHUM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
206 LINBOR	2(9)	7(8)	7(11)	4(13)	9(16)	10(8)	8(13)	7(6)	9(26)	10(11)	10(10)	5(T)	3(T)
219 PHYEMP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
218 SATDOU	-( )	-( )	-( )	-( )	1(T)	-( )	+(T)	+(T)	+(T)	1(15)	-( )	-( )	( )
145 VACCAE	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	1(15)	3(5)	-( )	-( )	( )
147 VACMYR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
148 VACSCO	-( )	-( )	-( )	-( )	3(6)	-( )	2(10)	-( )	1(15)	1(T)	3(T)	-( )	( )
FERNS AND ALLIED TAXA													
260 ADIPED	-( )	-( )	-( )	1(1)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
251 ATHFIL	6(13)	2(T)	3(1)	2(T)	2(T)	-( )	-( )	-( )	1(T)	1(T)	-( )	-( )	( )
255 GYMDRY	-( )	-( )	-( )	+(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
258 POLMUN	2(T)	3(1)	3(1)	3(8)	4(T)	2(8)	1(T)	3(T)	4(T)	-( )	-( )	1(T)	( )
259 PTEAQU	4(5)	1(T)	3(T)	5(1)	-( )	1(T)	4(4)	5(2)	2(3)	-( )	1(T)	3(T)	2(1)
GRAMINOIDS													
301 AGRSPI	-( )	-( )	-( )	-( )	-( )	-( )	+(3)	-( )	+(T)	-( )	-( )	-( )	1(1)
304 BROVUL	10(3)	9(4)	8(T)	9(3)	7(1)	5(T)	7(1)	7(2)	7(2)	6(3)	4(T)	3(2)	2(1)
305 CALCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
307 CALRUB	-( )	-( )	-( )	2(7)	2(5)	-( )	4(18)	7(13)	3(17)	6(6)	7(3)	3(5)	6(11)
309 CARGEY	2(T)	1(T)	-( )	2(1)	2(T)	1(T)	2(T)	3(1)	2(2)	4(1)	-( )	3(T)	4(1)
311 CARROS	6(1)	3(T)	2(T)	1(1)	2(6)	3(T)	2(T)	-( )	+(T)	-( )	1(T)	1(T)	1(1)
317 FESIDA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
325 LUZHIT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	( )

(con.)

SERIES H.T. PHASE	ABGR SETR	ABGR ASCA MEFE	ABGR ASCA TABR	ABGR ASCA ASCA	ABGR CLUN MEFE	ABGR CLUN TABR	ABGR CLUN XETE	ABGR CLUN PHMA	ABGR CLUN CLUN	ABGR LIBO LIBO	ABGR LIBO XETE	ABGR XETE COOC	ABGR XETE VAGL
NO. OF PLOTS	N= 9	N= 12	N= 21	N= 32	N= 17	N= 11	N= 38	N= 21	N= 27	N= 11	N= 7	N= 15	N= 16
PERENNIAL FORBS													
401 ACHMIL	-( )	-( )	-( )	+(T)	-( )	-( )	1(T)	1(T)	1(T)	3(T)	-( )	1(T)	( )
402 ACTRUB	9(4)	6(T)	5(5)	2(7)	1(T)	-( )	1(T)	+(3)	1(1)	-( )	-( )	-( )	( )
403 ADEBIC	6(4)	2(5)	6(2)	8(3)	1(T)	4(T)	3(T)	7(2)	8(4)	5(4)	1(3)	2(1)	( )
407 ANEPIP	9(4)	9(1)	10(2)	8(1)	9(2)	10(2)	9(1)	7(T)	8(2)	9(T)	10(T)	9(T)	6(1)
418 ARANUD	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	( )
420 AREMAC	8(2)	6(15)	4(T)	6(3)	2(1)	3(1)	4(T)	5(1)	5(2)	4(1)	4(T)	5(T)	5(1)
421 ARNCOR	1(15)	2(26)	+(T)	1(T)	1(T)	1(T)	1(1)	3(9)	5(7)	5(T)	1(T)	5(30)	1(38)
422 ARNLAT	-( )	3(32)	3(27)	2(32)	3(24)	-( )	4(14)	1(1)	1(6)	-( )	3(20)	1(2)	2(1)
564 ASACAU	9(13)	10(5)	10(5)	10(3)	-( )	-( )	1(T)	1(T)	+(T)	-( )	-( )	-( )	( )
426 ASTCON	-( )	-( )	1(1)	2(T)	1(T)	-( )	2(T)	5(T)	1(T)	1(T)	3(T)	1(T)	1(1)
431 BALSAG	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
442 CHIUMB	2(2)	6(T)	5(T)	5(1)	9(4)	10(2)	9(2)	3(1)	7(T)	8(3)	10(2)	9(T)	10(2)
445 CIRALP	7(24)	2(T)	+(T)	2(1)	-( )	1(T)	-( )	+(T)	1(T)	1(T)	-( )	1(T)	( )
447 CLIUNI	10(10)	10(5)	10(7)	10(3)	8(3)	9(7)	9(2)	10(4)	10(3)	-( )	-( )	1(T)	( )
449 COPOCC	10(14)	9(11)	10(13)	8(10)	10(13)	10(12)	9(14)	6(3)	9(16)	7(5)	10(7)	10(13)	5(T)
452 CORCAN	-( )	3(5)	4(2)	2(3)	5(10)	4(8)	4(7)	1(T)	3(7)	1(T)	-( )	1(T)	1(8)
454 DISHOO	1(15)	2(1)	2(T)	7(8)	1(2)	-( )	1(T)	7(1)	4(5)	-( )	-( )	-( )	( )
455 DISTRA	1(T)	-( )	+(T)	2(T)	-( )	-( )	1(19)	2(T)	3(T)	3(T)	1(T)	-( )	( )
458 DODJEF	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
465 FRAVES	-( )	2(T)	1(1)	6(T)	2(1)	1(T)	5(1)	7(1)	3(T)	7(T)	4(T)	5(T)	4(1)
467 FRAGAR	2(T)	-( )	+(T)	1(1)	-( )	2(2)	+(T)	-( )	2(T)	-( )	-( )	-( )	( )
466 FRAVIR	2(2)	1(T)	+(3)	-( )	1(T)	2(T)	1(2)	3(T)	2(3)	2(T)	-( )	1(T)	1(1)
471 GALTRI	10(2)	7(T)	5(T)	9(1)	4(T)	5(T)	6(T)	9(1)	7(2)	5(T)	1(T)	1(T)	1(1)
476 GOOOBL	4(T)	9(T)	7(T)	4(T)	7(T)	10(T)	7(T)	3(T)	6(T)	5(1)	6(T)	9(T)	5(1)
482 HEUCYL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	1(T)	-( )	-( )	( )
489 LIGCAN	-( )	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	( )
800 LIGVER	-( )	1(T)	-( )	1(T)	2(T)	-( )	2(1)	1(3)	+(3)	-( )	-( )	1(T)	( )
647 MERPAN	3(2)	-( )	+(T)	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
501 MITBRE	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
649 MITPEN	1(T)	-( )	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	( )
502 MITSTA	7(3)	5(T)	6(T)	5(T)	4(1)	5(1)	2(T)	4(T)	6(T)	5(T)	1(T)	2(T)	1(1)
505 OSMCHI	10(3)	8(T)	8(T)	8(T)	5(T)	6(T)	6(T)	7(T)	8(2)	6(T)	3(T)	4(T)	2(1)
507 PEDBRA	-( )	-( )	-( )	1(T)	1(T)	-( )	2(T)	-( )	1(T)	-( )	-( )	-( )	1(3)
508 PEDCON	-( )	1(T)	-( )	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	( )
509 PEDRAC	-( )	2(T)	1(T)	+(T)	5(T)	2(8)	4(T)	-( )	3(T)	3(T)	4(T)	7(T)	4(1)
519 POLPUL	3(7)	2(1)	2(1)	2(1)	2(T)	1(T)	1(T)	-( )	-( )	-( )	-( )	1(T)	1(1)
526 PYRASA	-( )	2(T)	2(1)	2(T)	6(2)	4(1)	3(1)	+(T)	1(T)	1(T)	3(T)	2(1)	2(1)
529 PYRSEC	1(T)	5(T)	4(T)	3(T)	5(1)	5(1)	5(T)	2(T)	3(1)	4(T)	4(T)	5(T)	4(T)
539 SENTRI	8(2)	1(T)	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	( )
542 SMIRAC	-( )	-( )	1(T)	3(T)	2(T)	-( )	2(T)	7(T)	3(1)	2(T)	1(T)	4(T)	1(1)
543 SMISTE	9(9)	8(2)	10(4)	10(4)	4(T)	6(T)	6(1)	9(6)	10(7)	6(T)	1(T)	4(T)	1(3)
546 STRAMP	1(T)	-( )	+(T)	+(T)	-( )	-( )	+(T)	-( )	+(T)	-( )	-( )	-( )	( )
810 SYNPLA	6(4)	3(2)	3(T)	1(T)	1(T)	-( )	1(1)	-( )	+(T)	-( )	-( )	-( )	( )
547 THAOCC	10(6)	7(2)	8(2)	8(2)	6(T)	5(2)	5(T)	7(T)	5(3)	5(T)	6(1)	6(3)	1(8)
548 TIATRI	7(7)	7(3)	10(2)	4(1)	6(T)	6(2)	2(4)	-( )	4(3)	-( )	-( )	-( )	( )
563 TRACAR	1(38)	-( )	-( )	+(T)	-( )	-( )	+(T)	-( )	1(8)	-( )	-( )	-( )	( )
560 TRIOVA	10(2)	10(T)	10(T)	6(T)	9(T)	8(1)	5(T)	3(T)	6(1)	5(T)	1(T)	6(T)	2(1)
551 VALSIT	6(7)	-( )	1(T)	1(T)	-( )	-( )	1(T)	-( )	1(T)	1(T)	-( )	1(T)	1(1)
552 VERVIR	1(T)	2(T)	+(T)	1(2)	1(T)	1(T)	-( )	+(T)	1(T)	-( )	-( )	-( )	( )
554 VIOADU	-( )	-( )	+(T)	1(T)	-( )	-( )	1(T)	2(T)	1(T)	2(T)	-( )	1(T)	( )
556 VIOGLA	9(7)	5(T)	5(2)	2(1)	1(T)	-( )	+(T)	-( )	1(T)	-( )	-( )	-( )	( )
557 VIOORB	7(11)	10(3)	10(2)	7(1)	9(4)	10(5)	8(2)	3(T)	7(1)	6(3)	9(T)	7(3)	6(T)
558 XERTEN	4(2)	9(13)	6(3)	4(T)	9(19)	8(16)	10(21)	1(T)	2(2)	5(2)	9(28)	10(21)	10(40)

CODE TO CONSTANCY VALUES

+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

(con.)

SERIES H.T. PHASE	ABGR PHMA COOC	ABGR PHMA PHMA	ABGR SPBE	PSME PHMA SMST	PSME PHMA PHMA	PSME VACA	PSME SYAL	PSME SPBE	PSME CARU ARUV	PSME CARU CARU	PSME FEID	PSME AGSP	
NO. OF PLOTS	N= 7	N= 18	N= 8	N= 22	N= 35	N= 4	N= 7	N= 7	N= 9	N= 5	N= 2	N= 3	N=
TREE SPECIES													
1 ABIGRA	10(23)	9(24)	10(26)	1(T)	2(T)	2(T)	1(T)	3(2)	-( )	-( )	-( )	3(T)	
2 ABILAS	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	4(T)	-( )	-( )	
3 BETPAP	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
6 LAROCC	-( )	2(19)	1(T)	2(10)	1(1)	2(T)	1(3)	-( )	4(8)	-( )	-( )	-( )	
7 PICENG	-( )	-( )	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
9 PINALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
10 PINCON	1(T)	3(16)	2(50)	-( )	1(1)	10(27)	1(15)	1(15)	7(14)	4(T)	5(T)	-( )	
12 PINMON	-( )	3(3)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
13 PINPON	3(9)	6(20)	6(14)	9(24)	8(28)	10(12)	10(35)	7(22)	4(62)	-( )	10(32)	10(38)	
16 PSEMEN	10(59)	9(53)	10(31)	10(73)	10(51)	10(29)	10(57)	10(40)	9(42)	10(54)	10(20)	10(15)	
17 THUPLI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
18 TSUHET	-( )	1(T)	1(15)	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
19 TSUMER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
SHRUB SPECIES													
102 ACEGLA	10(9)	7(8)	6(3)	5(6)	4(6)	-( )	1(3)	-( )	1(T)	4(T)	-( )	-( )	
104 ALNSIN	-( )	-( )	-( )	+(T)	1(8)	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	
105 AMEALN	9(3)	7(5)	9(3)	8(4)	7(5)	5(2)	9(5)	9(4)	2(T)	6(T)	5(T)	7(2)	
110 CRADOU	-( )	-( )	1(T)	-( )	-( )	-( )	1(T)	1(T)	-( )	-( )	-( )	3(T)	
111 HOLDIS	9(9)	8(17)	7(1)	9(15)	7(22)	2(T)	1(3)	-( )	1(T)	-( )	5(T)	3(3)	
113 LEDGLA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
115 LONUTA	4(T)	3(1)	5(4)	1(1)	2(T)	-( )	-( )	-( )	1(3)	4(2)	-( )	3(T)	
116 MENFER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
117 OPLHOR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
118 PACMYR	-( )	4(17)	1(38)	1(T)	1(1)	5(32)	1(T)	-( )	3(6)	2(T)	-( )	-( )	
119 PHILEW	4(6)	2(7)	1(38)	3(8)	1(13)	-( )	1(T)	1(T)	-( )	-( )	-( )	3(T)	
122 PHYMAL	9(16)	9(34)	5(1)	10(33)	9(34)	-( )	1(T)	1(3)	1(T)	2(3)	-( )	-( )	
124 PRUVIR	-( )	-( )	1(T)	2(5)	2(T)	-( )	4(T)	4(5)	-( )	-( )	5(T)	3(T)	
127 RHOALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
130 RIBLAC	-( )	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
133 ROSGYM	9(1)	9(8)	9(3)	8(5)	5(3)	5(T)	4(T)	4(1)	2(T)	2(3)	-( )	3(15)	
161 ROSNUT	-( )	1(T)	-( )	1(2)	+(3)	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	
134 ROSWOO	-( )	1(T)	-( )	-( )	1(T)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	
136 RUBPAR	6(1)	4(1)	5(T)	3(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
137 SALSCO	-( )	1(2)	2(8)	1(6)	1(1)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
142 SPIBET	7(1)	7(3)	10(2)	9(7)	8(5)	7(T)	10(9)	10(18)	6(4)	10(2)	10(T)	3(T)	
143 SYMALB	9(14)	8(16)	7(16)	10(19)	9(16)	5(19)	10(23)	7(3)	4(1)	6(1)	10(2)	3(3)	
144 TAXBRE	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
146 VACGLO	1(T)	4(3)	5(1)	-( )	1(2)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	
194 VACMEM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	2(T)	-( )	-( )	-( )	
LOW WOODY PLANTS AND DWARF SHRUBS													
201 ARCUVA	-( )	-( )	-( )	-( )	1(T)	10(35)	-( )	-( )	9(5)	-( )	5(3)	-( )	
203 BERREP	3(19)	6(4)	6(2)	6(T)	5(4)	10(4)	4(7)	1(T)	4(1)	8(2)	5(T)	-( )	
205 GAUHUM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
206 LINBOR	-( )	1(T)	2(T)	-( )	-( )	2(T)	-( )	-( )	1(3)	-( )	-( )	-( )	
219 PHYEMP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
218 SATDOU	-( )	2(T)	4(T)	1(19)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	3(15)	
145 VACCAE	-( )	-( )	-( )	-( )	-( )	10(1)	-( )	-( )	2(T)	-( )	-( )	-( )	
147 VACMYR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	-( )	
148 VACSCO	-( )	-( )	-( )	-( )	-( )	5(T)	-( )	-( )	1(15)	-( )	-( )	-( )	
FERNS AND ALLIED TAXA													
260 ADIPED	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
251 ATHFIL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
255 GYMDRY	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
258 POLMUN	7(8)	1(T)	1(T)	2(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
259 PTEAQU	3(T)	2(1)	1(3)	1(T)	1(2)	-( )	1(T)	4(1)	1(T)	-( )	5(T)	10(30)	
GRAMINOIDS													
301 AGRSPI	-( )	1(T)	-( )	1(T)	3(14)	2(15)	6(14)	7(31)	1(T)	4(2)	10(26)	10(15)	
304 BROVUL	9(T)	7(T)	4(1)	7(7)	3(2)	-( )	3(9)	-( )	-( )	-( )	-( )	-( )	
305 CALCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
307 CALRUB	3(2)	8(12)	7(23)	6(15)	7(32)	10(17)	6(5)	6(1)	9(54)	10(51)	5(3)	3(3)	
309 CARGEY	1(T)	3(T)	4(5)	5(17)	4(16)	5(9)	6(20)	3(9)	1(T)	10(19)	10(T)	3(T)	
311 CARROS	-( )	-( )	2(T)	1(T)	1(1)	2(T)	1(T)	3(T)	-( )	-( )	5(T)	3(3)	
317 FESIDA	-( )	-( )	-( )	-( )	1(2)	2(T)	3(2)	4(6)	4(T)	-( )	10(26)	7(3)	
325 LUZHIT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	

(con.)

APPENDIX C (Con.)

SERIES H.T. PHASE	ABGR PHMA COOC	ABGR PHMA PHMA	ABGR SPBE	PSME PHMA SMST	PSME PHMA PHMA	PSME VACA	PSME SYAL	PSME SPBE	PSME CARU ARUV	PSME CARU CARU	PSME FEID	PSME AGSP	
NO. OF PLOTS	N= 7	N= 18	N= 8	N= 22	N= 35	N= 4	N= 7	N= 7	N= 9	N= 5	N= 2	N= 3	N=
PERENNIAL FORBS													
401 ACHMIL	-( )	2(T)	4(T)	1(T)	5(1)	7(T)	3(2)	4(2)	7(T)	8(1)	10(T)	10(1)	
402 ACTRUB	-( )	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
403 ADEBIC	7(4)	7(2)	6(1)	6(2)	2(T)	-( )	-( )	-( )	-( )	-( )	5(T)	3(3)	
407 ANEPIP	7(2)	8(T)	7(4)	5(2)	3(T)	5(T)	1(T)	-( )	-( )	2(3)	-( )	-( )	
418 ARANUD	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
420 AREMAC	6(1)	3(4)	5(4)	6(8)	4(4)	5(T)	3(8)	-( )	-( )	2(T)	-( )	-( )	
421 ARNCOR	1(3)	3(19)	5(4)	8(14)	5(12)	-( )	4(19)	1(3)	4(5)	10(6)	-( )	-( )	
422 ARNLAT	3(2)	1(T)	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	2(3)	-( )	-( )	
564 ASACAU	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
426 ASTCON	-( )	4(T)	5(T)	5(1)	4(1)	-( )	-( )	-( )	-( )	4(T)	-( )	-( )	
431 BALSAG	-( )	-( )	-( )	+(T)	2(3)	-( )	1(3)	4(26)	1(T)	2(T)	5(T)	10(18)	
442 CHIUMB	1(T)	3(T)	5(T)	+(T)	1(T)	2(T)	-( )	-( )	3(1)	2(T)	-( )	-( )	
445 CIRALP	1(T)	2(T)	-( )	2(11)	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
447 CLIUNI	1(T)	1(T)	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
449 COPOCC	10(21)	2(T)	4(T)	+(T)	1(2)	-( )	-( )	-( )	-( )	2(T)	-( )	-( )	
452 CORCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
454 DISHOO	6(14)	4(T)	2(T)	6(3)	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
455 DISTRA	3(8)	3(T)	1(T)	4(T)	3(T)	-( )	-( )	-( )	1(T)	2(T)	-( )	-( )	
458 DODJEF	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
465 FRAVES	6(T)	7(5)	4(T)	6(6)	5(3)	5(2)	1(T)	-( )	4(T)	2(3)	5(T)	3(3)	
467 FRAGAR	-( )	-( )	1(15)	2(2)	2(5)	-( )	4(2)	4(T)	3(5)	6(T)	-( )	-( )	
466 FRAVIR	-( )	1(T)	2(T)	1(T)	2(1)	5(T)	1(T)	1(T)	-( )	-( )	5(T)	7(2)	
471 GALTRI	10(3)	7(3)	6(3)	9(3)	3(T)	-( )	1(T)	1(T)	-( )	-( )	-( )	-( )	
476 GOOOBL	4(1)	4(T)	4(T)	4(T)	3(T)	-( )	-( )	3(T)	2(T)	4(T)	-( )	-( )	
482 HEUCYL	1(T)	1(T)	1(T)	1(T)	2(T)	5(2)	3(T)	1(T)	6(1)	8(T)	-( )	-( )	
489 LIGCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
800 LIGVER	7(2)	1(T)	2(T)	1(8)	1(5)	-( )	1(15)	1(38)	-( )	-( )	-( )	-( )	
647 MERPAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
501 MITBRE	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
649 MITPEN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
502 MITSTA	3(2)	3(2)	5(1)	5(2)	2(T)	2(T)	-( )	-( )	1(T)	2(T)	-( )	-( )	
505 OSMCHI	4(T)	7(T)	6(T)	9(1)	3(1)	-( )	3(T)	-( )	-( )	4(T)	-( )	-( )	
507 PEDBRA	-( )	-( )	1(T)	-( )	+(T)	-( )	-( )	-( )	1(T)	2(T)	-( )	-( )	
508 PEDCON	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
509 PEDRAC	1(T)	-( )	2(T)	+(T)	+(T)	-( )	-( )	-( )	-( )	2(T)	-( )	-( )	
519 POLPUL	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
526 PYRASA	-( )	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
529 PYRSEC	1(T)	1(T)	2(T)	+(T)	-( )	-( )	-( )	-( )	2(T)	2(T)	-( )	-( )	
539 SENTRI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
542 SMIRAC	1(T)	7(T)	5(T)	9(4)	6(2)	-( )	6(T)	4(1)	3(1)	8(T)	-( )	-( )	
543 SMISTE	7(4)	7(2)	5(T)	6(3)	2(T)	-( )	-( )	-( )	-( )	2(T)	-( )	-( )	
546 STRAMP	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
810 SYNPLA	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
547 THAOCC	6(T)	6(T)	2(T)	5(4)	4(4)	-( )	-( )	-( )	2(T)	6(1)	-( )	-( )	
548 TIATRI	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
563 TRACAR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
560 TRIOVA	4(T)	2(T)	2(T)	2(1)	1(T)	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
551 VALSIT	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
552 VERVIR	-( )	-( )	-( )	1(T)	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
554 VIOADU	1(T)	2(T)	2(2)	2(1)	3(T)	-( )	1(T)	-( )	1(T)	2(T)	-( )	3(T)	
556 VIOGLA	1(T)	-( )	-( )	-( )	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
557 VIOORB	-( )	1(T)	1(T)	+(T)	-( )	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
558 XERTEN	-( )	1(2)	2(T)	-( )	1(19)	5(3)	-( )	-( )	1(T)	2(15)	-( )	-( )	

CODE TO CONSTANCY VALUES

+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

(con.)

SERIES H.T. PHASE	PIPO PHMA	PIPO SYAL	PIPO FEID	PIPO AGSP	PICO VASC	PICO VACA	PICO XETE	
NO. OF PLOTS	N= 7	N= 14	N= 13	N= 8	N= 7	N= 3	N= 2	N=
TREE SPECIES								
1 ABIGRA	-( )	-( )	-( )	-( )	1(T)	3(T)	5(T)	
2 ABILAS	-( )	-( )	-( )	-( )	7(T)	10(T)	10(T)	
3 BETPAP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
6 LAROCC	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
7 PICENG	-( )	-( )	-( )	-( )	3(T)	3(T)	10(T)	
9 PINALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
10 PINCON	-( )	-( )	-( )	-( )	10(66)	10(74)	10(80)	
12 PINMON	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
13 PINPON	10(65)	10(52)	10(50)	10(23)	-( )	-( )	-( )	
16 PSEMEN	-( )	1(T)	1(T)	1(T)	1(T)	3(T)	5(T)	
17 THUPLI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
18 TSUHET	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
19 TSUMER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
SHRUB SPECIES								
102 ACEGLA	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	
104 ALNSIN	-( )	-( )	-( )	-( )	3(T)	-( )	5(3)	
105 AMEALN	10(4)	9(6)	4(T)	1(T)	-( )	3(T)	-( )	
110 CRADOU	9(1)	6(12)	-( )	-( )	-( )	-( )	-( )	
111 HOLDIS	9(15)	1(2)	1(T)	-( )	-( )	-( )	-( )	
113 LEDGLA	-( )	-( )	-( )	-( )	1(T)	-( )	-( )	
115 LONUTA	-( )	-( )	-( )	-( )	1(T)	3(T)	-( )	
116 MENFER	-( )	-( )	-( )	-( )	-( )	-( )	5(T)	
117 OPLHOR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
118 PACMYR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
119 PHILEW	1(15)	2(2)	-( )	1(T)	-( )	-( )	-( )	
122 PHYMAL	10(65)	1(T)	1(T)	1(T)	-( )	-( )	-( )	
124 PRUVIR	6(8)	6(2)	1(T)	1(T)	-( )	-( )	-( )	
127 RHOALB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
130 RIBLAC	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
133 ROSGYM	-( )	1(T)	2(T)	1(T)	-( )	3(T)	-( )	
161 ROSNUT	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
134 ROSWOO	10(4)	7(8)	-( )	1(T)	-( )	-( )	-( )	
136 RUBPAR	1(T)	-( )	-( )	-( )	-( )	-( )	-( )	
137 SALSCO	-( )	-( )	-( )	1(T)	4(T)	-( )	-( )	
142 SPIBET	10(10)	6(19)	2(1)	1(T)	9(T)	10(T)	5(T)	
143 SYMALB	10(32)	9(36)	2(T)	2(T)	-( )	3(T)	-( )	
144 TAXBRE	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
146 VACGLO	-( )	-( )	-( )	-( )	4(2)	3(T)	10(50)	
194 VACMEM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
LOW WOODY PLANTS AND DWARF SHRUBS								
201 ARCUVA	-( )	-( )	-( )	-( )	4(1)	10(T)	-( )	
203 BERREP	6(3)	4(15)	-( )	1(T)	-( )	-( )	-( )	
205 GAUHUM	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
206 LINBOR	-( )	-( )	-( )	-( )	-( )	3(T)	-( )	
219 PHYEMP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
218 SATDOU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
145 VACCAE	4(T)	1(3)	-( )	-( )	3(2)	10(38)	-( )	
147 VACMYR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
148 VACSCO	-( )	-( )	-( )	-( )	10(55)	10(46)	5(3)	
FERNS AND ALLIED TAXA								
260 ADIPED	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
251 ATHFIL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
255 GYMDRY	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
258 POLMUN	3(T)	1(T)	-( )	-( )	-( )	-( )	-( )	
259 PTEAQU	-( )	1(T)	2(2)	-( )	-( )	-( )	-( )	
GRAMINOIDS								
301 AGRSPI	3(3)	6(6)	7(13)	10(47)	-( )	-( )	-( )	
304 BROVUL	7(3)	1(T)	-( )	-( )	-( )	-( )	-( )	
305 CALCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
307 CALRUB	9(6)	4(10)	2(6)	1(T)	10(10)	10(19)	10(19)	
309 CARGEY	6(15)	1(20)	2(6)	1(T)	-( )	3(T)	5(T)	
311 CARROS	1(3)	2(2)	2(T)	-( )	1(T)	-( )	-( )	
317 FESIDA	-( )	1(T)	10(61)	2(2)	-( )	-( )	-( )	
325 LUZHIT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	

(con.)

APPENDIX C (Con.)

SERIES H.T. PHASE	PIPO PHMA	PIPO SYAL	PIPO FEID	PIPO AGSP	PICO VASC	PICO VACA	PICO XETE	
NO. OF PLOTS	N= 7	N= 14	N= 13	N= 8	N= 7	N= 3	N= 2	N=
PERENNIAL FORBS								
401 ACHMIL	7(2)	7(T)	9(1)	7(1)	-( )	10(T)	-( )	
402 ACTRUB	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
403 ADEBIC	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
407 ANEPIP	1(T)	-( )	-( )	-( )	4(T)	10(T)	5(T)	
418 ARANUD	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
420 AREMAC	4(7)	1(T)	1(T)	-( )	-( )	3(T)	5(T)	
421 ARNCOR	1(3)	-( )	1(T)	1(T)	-( )	3(T)	-( )	
422 ARNLAT	-( )	-( )	-( )	-( )	-( )	-( )	5(15)	
564 ASACAU	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
426 ASTCON	1(3)	-( )	-( )	-( )	-( )	-( )	-( )	
431 BALSAG	-( )	4(7)	9(5)	9(3)	-( )	-( )	-( )	
442 CHIUMB	1(T)	-( )	-( )	-( )	7(T)	7(2)	10(T)	
445 CIRALP	3(T)	-( )	-( )	-( )	-( )	-( )	-( )	
447 CLIUNI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
449 COPOCC	-( )	-( )	-( )	-( )	-( )	-( )	5(T)	
452 CORCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
454 DISHOO	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
455 DISTRA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
458 DODJEF	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
465 FRAVES	-( )	3(T)	1(T)	1(T)	-( )	-( )	-( )	
467 FRAGAR	9(2)	2(T)	2(2)	-( )	-( )	-( )	-( )	
466 FRAVIR	-( )	-( )	-( )	-( )	1(T)	7(2)	-( )	
471 GALTRI	1(T)	1(T)	1(T)	-( )	-( )	-( )	-( )	
476 GOOOBL	-( )	-( )	-( )	-( )	-( )	-( )	5(T)	
482 HEUCYL	6(T)	3(2)	-( )	1(T)	-( )	-( )	-( )	
489 LIGCAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
800 LIGVER	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
647 MERPAN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
501 MITBRE	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
649 MITPEN	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
502 MITSTA	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
505 OSMCHI	7(3)	1(2)	-( )	-( )	-( )	-( )	-( )	
507 PEDBRA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
508 PEDCON	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
509 PEDRAC	-( )	-( )	-( )	-( )	-( )	3(T)	-( )	
519 POLPUL	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
526 PYRASA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
529 PYRSEC	-( )	-( )	-( )	-( )	-( )	3(T)	5(T)	
539 SENTRI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
542 SMIRAC	1(T)	1(T)	-( )	-( )	-( )	-( )	-( )	
543 SMISTE	-( )	1(T)	-( )	-( )	-( )	-( )	-( )	
546 STRAMP	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
810 SYNPLA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
547 THAOCC	4(11)	-( )	-( )	-( )	-( )	3(T)	-( )	
548 TIATRI	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
563 TRACAR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
560 TRIOVA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
551 VALSIT	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
552 VERVIR	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
554 VIOADU	6(T)	1(T)	-( )	-( )	-( )	3(T)	-( )	
556 VIOGLA	-( )	-( )	-( )	-( )	-( )	-( )	-( )	
557 VIOORB	-( )	-( )	-( )	-( )	-( )	7(T)	10(T)	
558 XERTEN	-( )	-( )	-( )	-( )	9(7)	10(6)	10(26)	

CODE TO CONSTANCY VALUES

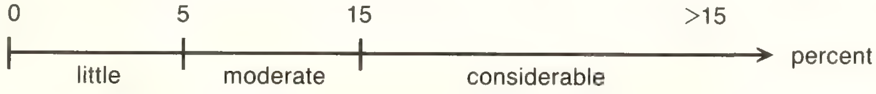
+ = 0-5%	2 = 15-25%	4 = 35-45%	6 = 55-65%	8 = 75-85%	10 = 95-100%
1 = 5-15%	3 = 25-35%	5 = 45-55%	7 = 65-75%	9 = 85-95%	

(CANOPY COVERAGE EXPRESSED TO NEAREST %)

APPENDIX D: SUBSTRATE FEATURES OF NORTHERN IDAHO HABITAT TYPES

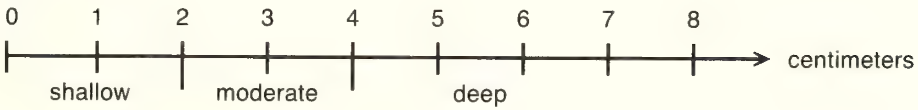
The following table presents soils data by habitat type and phase in format similar to that for vegetative data (appendix C). Coarse-fragment rock types are expressed as a percentage of the stands in which a given rock type was the apparent residual parent material. Note that ash and loess content, which constitute at least a fraction of the parent material in a substantial portion of the plots, are noted only in the h.t. soils section narrative because their contribution could not be unambiguously ascertained. Textural classes are also shown as a percentage of stands having a given soil texture. Mean values ($\bar{x}$) are presented for all other data categories. "Upper profile" and "lower profile" are arbitrarily defined respectively as (1) that profile portion including any A horizon or the uppermost horizon if an A horizon is not present and (2) that root-containing portion of the profile above the C or R horizons and below the "upper profile"; both terms may express an average of more than one horizon. The terminology diagramed below and used in the narratives is based primarily on USDA Soil Conservation Service (1975) definitions, with some modifications.

Surface Rock Exposed (includes cobbles, stones, and fixed rock; material >3 inches [7.6 cm] diameter)



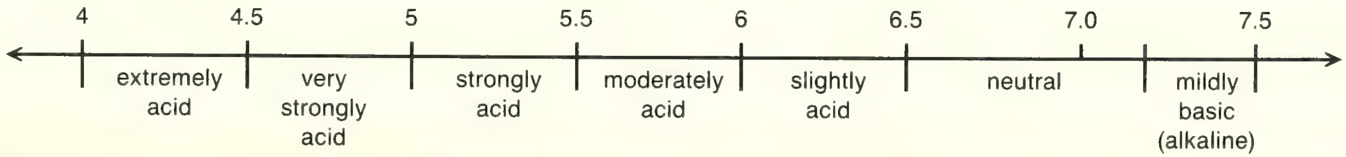
Bare Soil Exposed (includes soil and gravel; material <3 inches [7.6 cm]

Duff Depth



Gravel Content

Reaction (pH units)



(con.)

APPENDIX D (Con.)

Soil characteristics	*Tsuga heterophylla* series							*Thuja plicata* series										
	GYDR h.t.	ASCA h.t.			CLUN			OPHO	ATFI		ADPE	GYDR	ASCA			CLUN		
		ARNU phase	MEFE phase	ASCA phase	ARNU phase	MEFE phase	CLUN phase		ATFI	ADPE			MEFE	TABR	ASCA	MEFE	XETE	CLUN
	n = 6	n = 4	n = 3	n = 15	n = 6	n = 4	n = 16	n = 4	n = 6	n = 2	n = 4	n = 4	n = 5	n = 2	n = 11	n = 3	n = 3	n = 6
COARSE FRAGMENT ROCK TYPES (percent of stands)																		
SEDIMENTARY																		
Calcareous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Noncalcareous	50	—	67	13	—	—	19	—	33	—	25	25	—	—	9	—	33	17
METAMORPHIC																		
Argillite	—	—	—	—	—	—	—	—	—	—	—	—	—	100	27	33	—	—
Quartzite	17	—	33	27	—	50	25	—	50	—	—	75	60	—	18	67	67	50
Gneiss & schist & phyllite	—	—	—	—	—	—	—	—	—	—	75	—	40	—	18	—	—	33
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9	—	—	—
IGNEOUS																		
Basalt & andesite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dacite, trachyte, & latite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhyolite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other volcanics	—	—	—	7	—	25	—	—	—	—	—	—	—	—	9	—	—	—
Quartz monzonite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Granitics (undifferentiated)	—	—	—	13	—	25	25	—	16	—	—	—	—	—	—	—	—	—
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MIXED (e.g., alluvium, glacial till)	33	100	—	40	100	—	31	100	—	100	—	—	—	—	9	—	—	—
SUBSTRATE CHARACTERISTICS																		
EFFECTIVE ROOTING DEPTH ($\bar{x}$ in cm)	56	35	42	38	56	55	45	31	34	100	62	45	46	56	50	41	43	61
EXPOSED ROCK ($\bar{x}$ in %)	0	<1	<1	<1	0	<1	<1	0	0	0	0	<1	0	0	0	<1	<1	0
EXPOSED SOIL ($\bar{x}$ in %)	0	0	<1	<1	0	0	<1	0	0	0	<1	0	0	0	0	0	<1	0
DUFF DEPTH ($\bar{x}$ in cm)	5.6	3.0	5.0	4.0	4.4	4.3	5.6	4.0	5.4	4.8	4.2	8.1	4.5	5.3	5.2	5.1	5.1	4.7
GRAVEL CONTENT UPPER PROFILE ($\bar{x}$ in %)	8	32	5	20	2	24	15	16	10	5	5	25	13	3	20	22	15	11
GRAVEL CONTENT LOWER PROFILE ($\bar{x}$ in %)	8	40	55	41	14	44	24	40	25	5	5	43	31	7	25	50	35	12
REACTION UPPER PROFILE ($\bar{x}$ pH)	6.0	5.4	5.4	6.1	6.0	5.9	5.6	5.7	5.7	6.4	6.5	6.2	6.1	6.4	6.4	5.7	6.1	6.5
REACTION LOWER PROFILE ($\bar{x}$ pH)	6.1	5.8	5.7	6.0	6.3	5.7	6.1	5.7	5.6	6.6	6.1	6.3	6.2	6.2	6.4	5.9	5.8	6.3
TEXTURE CLASS (upper profile, % occurrence)																		
Sand & loamy sand	—	—	—	—	—	—	—	—	33	—	25	—	—	—	9	—	—	—
Sandy loam	—	25	—	—	—	—	—	25	—	—	—	—	—	—	—	—	—	17
Loam	17	25	—	13	—	—	—	25	—	—	—	—	—	50	18	—	—	17
Silt loam & silt	67	50	100	67	60	100	—	50	16	100	75	75	40	50	64	67	100	33
Silty clay loam & clay loam	17	—	—	20	40	—	25	—	50	—	—	25	60	—	9	33	—	33

(con.)

APPENDIX D (Con.)

Soil characteristics	*Tsuga mertensiana* series								*Abies lasiocarpa* series													
	STAM	CLUN		MEFE		XETE			CACA		STAM		CLUN		MEFE		VACA	XETE				LUHI
	MEFE	MEFE	XETE	XETE	LUHI	XETE	VASC	LUHI	LEGL	VACA	MEFE	LICA	MEFE	XETE	COOC	LUHI		COOC	VAGL	VASC	LUHI	
	n = 3	n = 10	n = 4	n = 4	n = 9	n = 7	n = 13	n = 7	n = 4	n = 2	n = 9	n = 8	n = 6	n = 6	n = 4	n = 4	n = 4	n = 7	n = 4	n = 10	n = 7	n = 3
	COARSE FRAGMENT ROCK TYPES (percent of stands)																					
SEDIMENTARY																						
Calcareous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Noncalcareous	—	10	—	—	22	—	—	—	—	—	—	38	—	—	—	—	—	—	—	—	—	—
METAMORPHIC																						
Argillite	33	20	—	—	—	29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Quartzite	—	30	75	—	22	43	31	43	—	—	11	—	17	33	—	—	—	14	25	—	—	—
Gneiss & schist & phyllite	33	—	—	50 25	22	—	23	14	—	—	—	25	17	17	25	—	25	28	25	—	28	—
Miscellaneous	33	10	25	—	—	14	8	—	—	—	—	—	—	—	—	—	—	—	—	10	14	—
IGNEOUS																						
Basalt & andesite	—	—	—	—	—	—	—	—	—	—	—	—	—	17	—	—	—	—	—	—	—	—
Dacite, trachyte, & latite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhyolite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Other volcanics	—	—	—	—	—	—	—	—	—	—	—	12	—	—	—	—	—	—	—	—	—	—
Quartz monzonite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Granitics (undifferentiated)	—	30	—	50	33	14	38	43	100	50	66	12	67	17	75	100	50	57	50	80	57	100
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	17	—	—	—	—	—	10	—	—
MIXED																						
(e.g., alluvium, glacial till)	—	—	—	—	—	—	—	—	—	50	33	12	—	—	—	—	25	—	—	—	—	—
	SUBSTRATE CHARACTERISTICS																					
EFFECTIVE ROOTING DEPTH (x̄ in cm)	55	49	38	—	33	46	39	37	37	57	36	39	57	45	46	38	41	41	50	48	33	32
EXPOSED ROCK (x̄ in %)	0	1	<1	<1	1	1	2	1	<1	<1	<1	<1	0	<1	<1	6	<1	<1	<1	1	1	<1
EXPOSED SOIL (x̄ in %)	<1	<1	<1	0	<1	<1	2	<1	0	0	0	<1	0	0	1	0	0	<1	0	2	2	<1
DUFF DEPTH (x̄ in cm)	2.6	3.0	2.7	2.9	2.7	2.2	2.2	2.3	2.2	2.5	3.7	3.3	3.4	2.8	3.2	1.1	3.2	2.3	2.1	1.7	1.7	1.8
GRAVEL CONTENT UPPER PROFILE (x̄ in %)	30	10	21	15	15	23	12	22	13	15	16	14	21	16	—	30	12	19	14	13	25	22
GRAVEL CONTENT LOWER PROFILE (x̄ in %)	47	17	32	22	20	34	23	32	30	27	27	17	28	22	—	60	30	34	44	24	33	30
REACTION UPPER PROFILE (x̄ pH)	5.2	5.7	5.4	5.2	4.5	5.1	5.0	5.1	5.2	4.9	5.0	5.4	5.9	5.8	5.5	4.6	5.9	5.9	5.8	5.6	5.0	4.5
REACTION LOWER PROFILE (x̄ pH)	5.5	5.6	5.4	6.0	5.4	5.7	5.6	5.6	5.7	5.6	5.5	5.6	5.9	5.6	5.8	5.3	6.1	5.9	5.9	5.7	5.7	5.2
TEXTURE CLASS (upper profile, % occurrence)																						
Sand & loamy sand	33	—	—	—	—	—	8	14	—	—	11	—	—	—	—	—	—	43	25	20	28	—
Sandy loam	—	—	—	—	—	—	8	—	50	—	—	12	17	17	25	—	25	14	—	10	—	—
Loam	—	20	25	50	27	43	—	—	25	50	22	12	17	17	—	—	75	—	25	30	14	66
Silt loam & silt	67	70	50	50	54	57	58	57	—	50	67	63	50	50	75	100	—	14	50	40	57	33
Silty clay loam & clay loam	—	10	25	—	18	—	25	29	25	—	—	12	17	17	—	—	—	28	—	—	—	—

(con.)

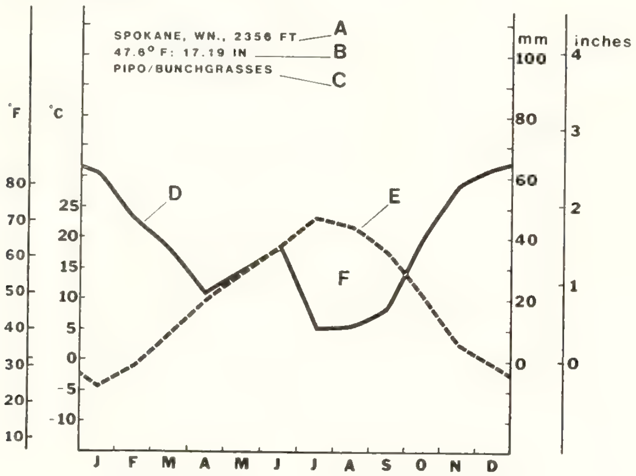
APPENDIX D (Con.)

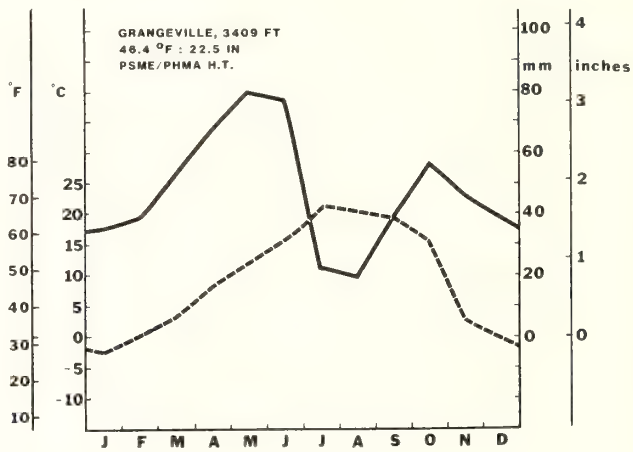
Soil characteristics	*Abies grandis* series															*Pseudotsuga menziesii* series			
	ASCA			CLUN					LIBO		XETE		PHMA		SPBE	PHMA		VACA	CARU
	MEFE	TABR	ASCA	MEFE	TABR	XETE	PHMA	CLUN	XETE	LIBO	COOC	VAGL	COOC	PHMA		SMST	PHMA		
	n = 4	n = 3	n = 13	n = 3	n = 2	n = 16	n = 12	n = 7	n = 4	n = 3	n = 3	n = 10	n = 2	n = 10	n = 3	n = 6	n = 10	n = 2	n = 3
	COARSE FRAGMENT ROCK TYPES (percent of stands)																		
SEDIMENTARY																			
Calcareous	—	—	—	—	—	—	—	14	—	—	—	—	—	—	—	—	10	—	—
Noncalcareous	—	—	8	—	—	6	—	—	—	33	—	—	—	—	50	—	—	—	—
METAMORPHIC																			
Argillite	—	—	15	—	—	—	8	14	—	—	—	—	—	11	—	—	—	—	33
Quartzite	50	—	15	—	—	31	16	29	25	—	33	20	—	22	—	33	20	—	33
Gneiss & schist & phyllite	—	66	8	33	—	25	25	14	—	—	—	—	—	—	—	—	10	—	—
Miscellaneous	—	—	31	—	—	—	—	—	—	—	—	10	—	—	—	—	—	—	—
IGNEOUS																			
Basalt & andesite	—	—	8	33	—	—	8	—	—	—	33	10	—	33	—	50	—	—	—
Dacite, trachyte, & latite	—	—	—	—	—	—	16	—	—	—	—	—	—	—	—	—	—	—	—
Rhyolite	—	—	—	—	—	—	8	—	—	—	—	—	—	11	—	—	—	—	—
Other volcanics	50	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—
Quartz monzonite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Granitics (undifferentiated)	—	33	8	33	100	31	8	29	75	—	33	40	100	22	50	17	60	—	—
Miscellaneous	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MIXED (e.g., alluvium, glacial till)	—	—	8	—	—	—	8	—	—	67	—	20	—	—	—	—	—	100	33
	SUBSTRATE CHARACTERISTICS																		
EFFECTIVE ROOTING DEPTH ($\bar{x}$ in cm)	67	66	50	60	70	52	44	40	45	51	52	44	36	48	52	38	54	75	37
EXPOSED ROCK ($\bar{x}$ in %)	0	0	<1	0	0	<1	<1	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	1
EXPOSED SOIL ($\bar{x}$ in %)	0	0	<1	0	0	<1	<1	<1	<1	0	<1	<1	<1	<1	<1	1	1	<1	<1
DUFF DEPTH ($\bar{x}$ in cm)	5.5	5.3	4.6	4.7	5.1	4.2	4.1	4.3	3.6	4.6	4.3	3.2	4.2	3.5	2.5	4.2	3.4	2.0	3.1
GRAVEL CONTENT UPPER PROFILE ($\bar{x}$ in %)	14	1	14	5	5	18	17	20	28	20	35	15	35	25	20	10	32	5	33
GRAVEL CONTENT LOWER PROFILE ($\bar{x}$ in %)	24	3	19	5	15	30	25	32	40	42	30	35	45	30	25	17	37	15	50
REACTION UPPER PROFILE ($\bar{x}$ pH)	5.6	6.5	6.4	6.2	7.0	6.1	6.3	6.0	5.9	6.6	6.4	6.1	6.7	6.4	6.1	6.6	6.5	5.9	6.0
REACTION LOWER PROFILE ($\bar{x}$ pH)	6.0	6.1	6.1	6.1	6.9	6.1	6.1	5.9	5.9	6.8	6.0	6.0	6.7	6.1	6.3	6.2	6.5	6.1	5.7
TEXTURE CLASS (upper profile, % occurrence)																			
Sand & loamy sand	25	—	8	—	—	30	33	14	—	—	33	—	—	—	—	—	20	50	—
Sandy loam	25	—	8	—	—	—	—	29	25	—	—	—	50	10	—	17	20	—	—
Loam	25	33	8	33	50	8	8	29	50	—	—	22	—	20	33	—	10	—	—
Silt loam & silt	25	66	61	66	50	38	33	—	25	33	—	77	—	60	66	50	30	50	33
Silty clay loam & clay loam	—	—	16	—	—	23	25	29	—	67	67	11	50	10	—	33	20	—	66

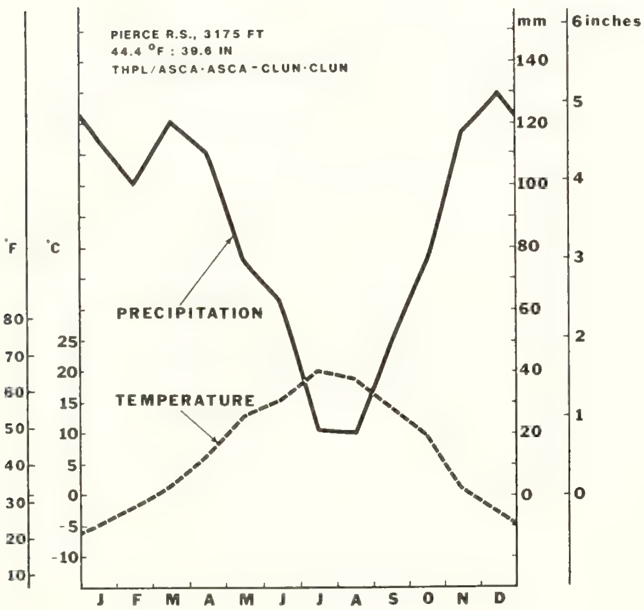
APPENDIX E: CLIMATE DIAGRAMS (WALTER 1973) FOR WEATHER STATIONS WITHIN OR PROXIMAL TO SELECTED NORTHERN IDAHO HABITAT TYPES; ORDER OF PRESENTATION IS FROM STATIONS OF WARM-DRY ENVIRONMENTS TO THOSE OF COLD-MOIST ENVIRONMENTS

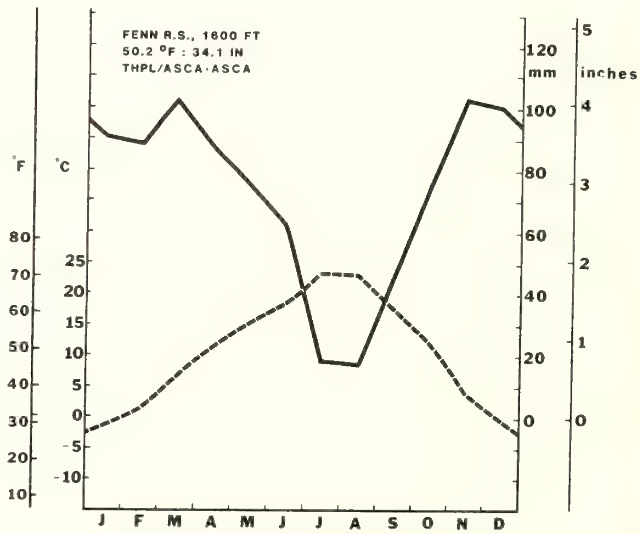
KEY TO WALTER-TYPE CLIMATE DIAGRAMS

A. Station locations, elevation (feet)
B. Mean annual temperature & precipitation
C. Series/Habitat Type • Phase
D. Annual march of precipitation
E. Annual march of temperature
F. Area where temperature curve exceeds the precipitation curve represents hypothetical period of drought (when scaled 20 mm precipitation per 10°C)
G. Following diagrams arranged by series, from warm-dry to cold-wet environments

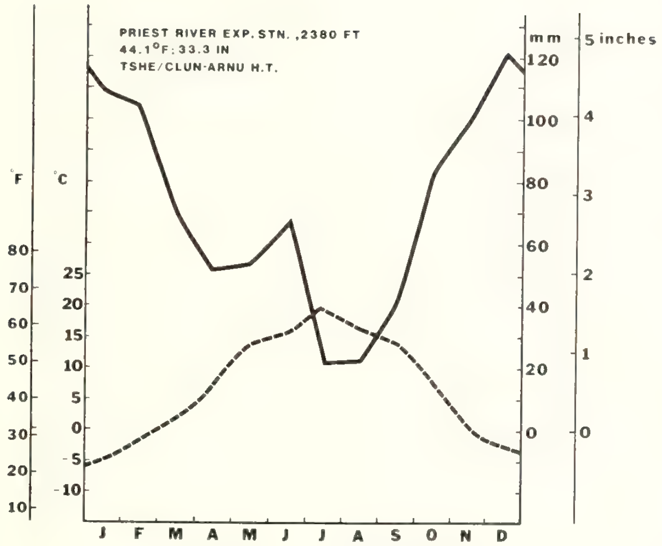


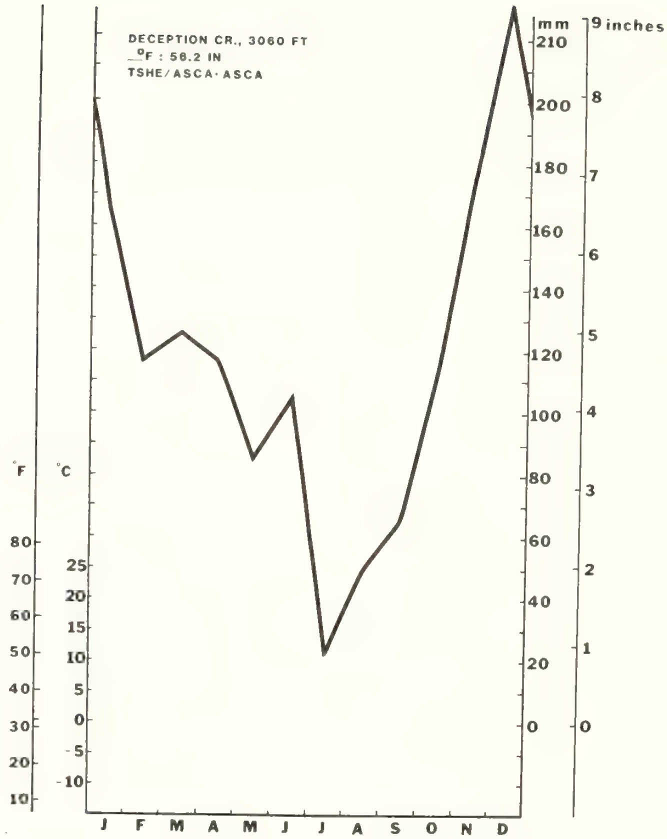


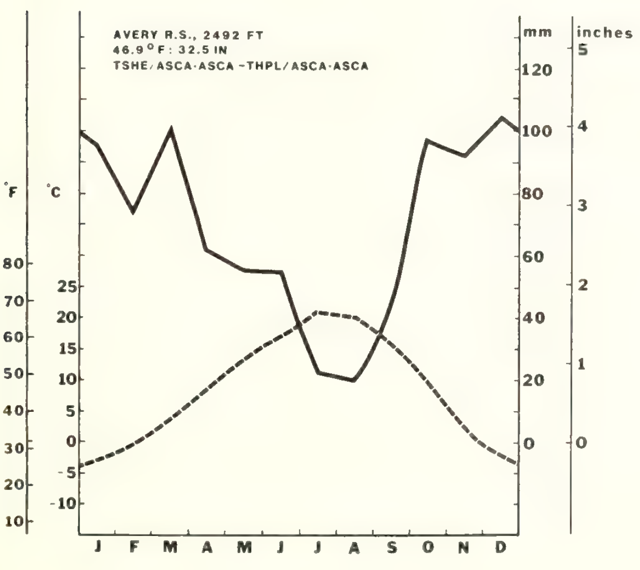


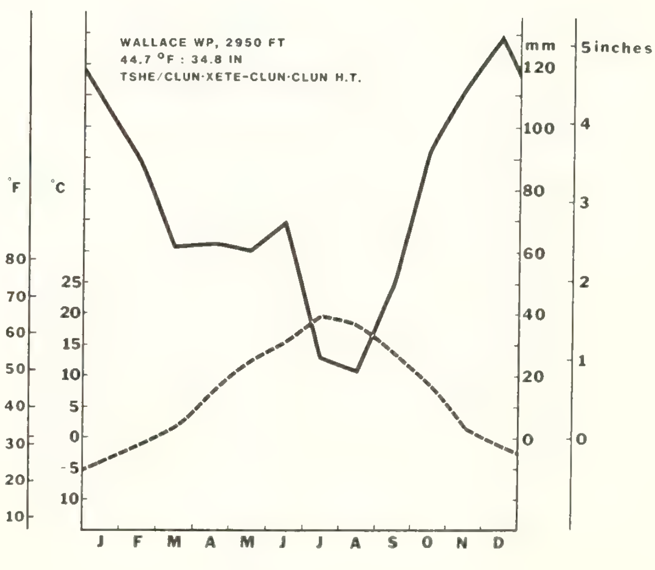


APPENDIX E (Con.)

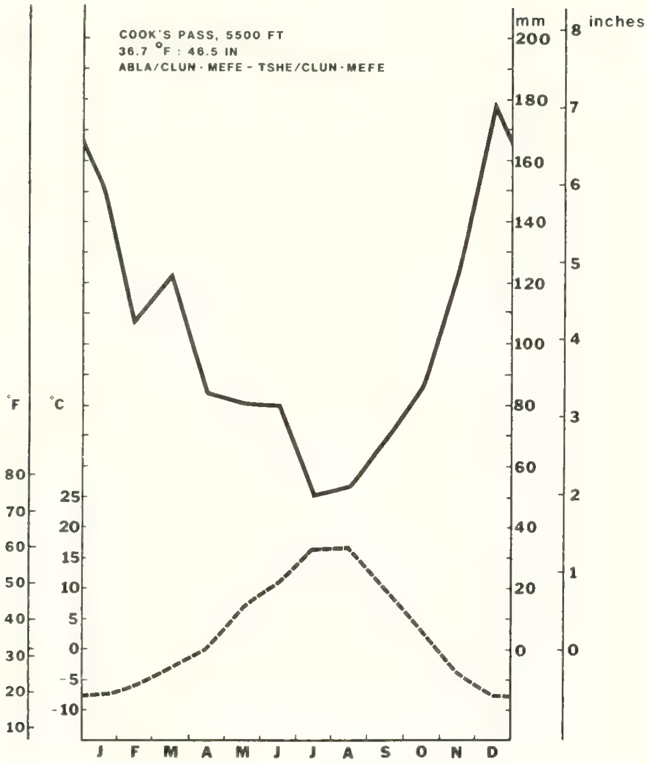


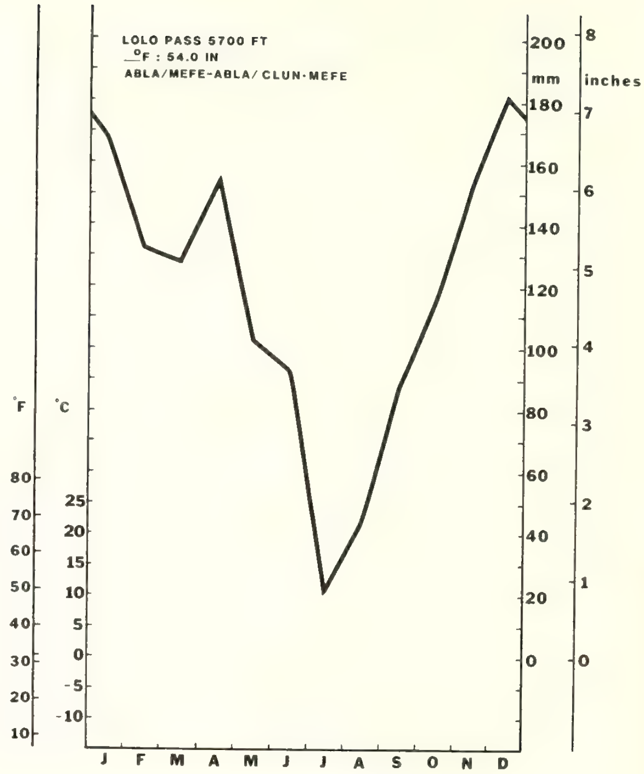


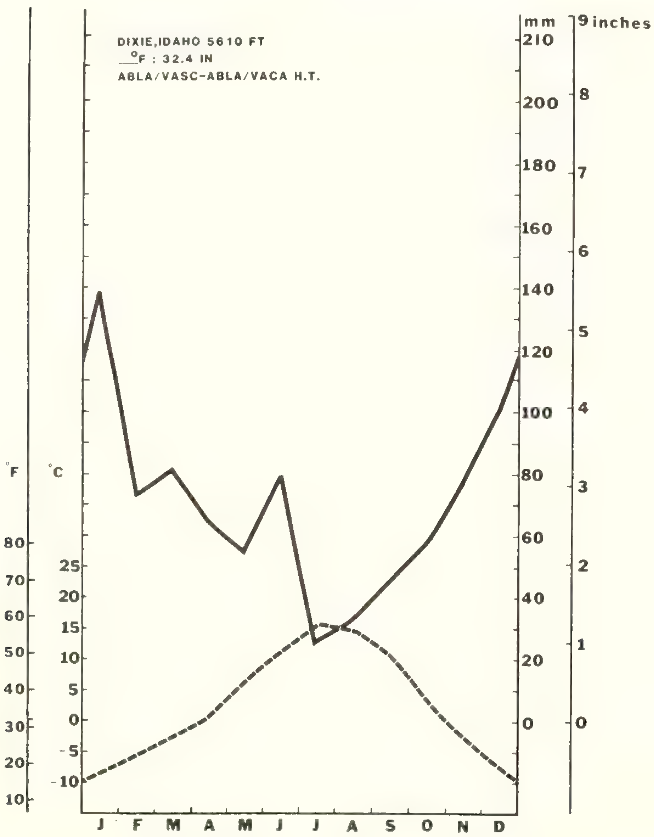


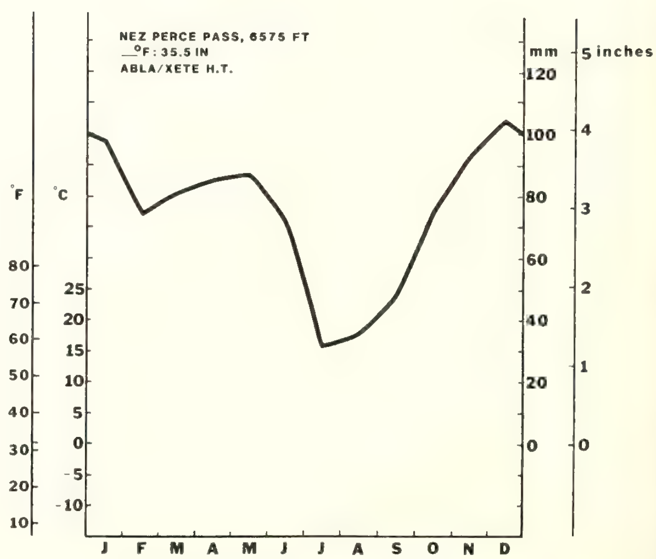


(con.)


COOK'S PASS, 5500 FT
36.7 °F : 46.5 IN
ABLA/CLUN - MEFE - TSHE/CLUN - MEFE
mm
inches
°F
°C
J F M A M J J A S O N D


LOLO PASS 5700 FT
__°F : 54.0 IN
ABLA/MEFE-ABLA/ CLUN-MEFE
mm
inches
°F
°C
J F M A M J J A S O N D


DIXIE,IDAHO 5610 FT
__°F : 32.4 IN
ABLA/VASC-ABLA/VACA H.T.
mm
inches
°F
°C
J F M A M J J A S O N D


NEZ PERCE PASS, 6575 FT
__°F : 35.5 IN
ABLA/XETE H.T.
mm
inches
°F
°C
J F M A M J J A S O N D

APPENDIX F: MEAN BASAL AREA (FT^2/ACRE) AND SITE INDEXES (50-YEAR INDEX AGE) FOR NORTHERN IDAHO, BY SERIES/HABITAT TYPE-PHASE (MEANS SHOWN WHERE THE NUMBER OF STANDS, n ⩾3; CONFIDENCE LIMITS [95 PERCENT] GIVEN FOR ESTIMATING THE MEAN IF n ⩾5; ? INDICATES LACK OF DATA FOR POTENTIALLY IMPORTANT SPECIES)

Series/habitat type-phase	Basal area	PIPO	PSME	PICO	LAOC	ABGR	PIMO	THPL	PIEN	ABLA	TSME
TSHE/GYDR	230 ± 49		.	.	75 ± ?	?	70 ± ?	68 ± 7	77 ± ?	.	.
/ASCA-ARNU	225 ± 67	?	?	?	?	66 ± ?	?	?	.	.	.
/ASCA-MEFE	194 ± 24	.	?	?	?	?	?	?	?	?	.
/ASCA-ASCA	236 ± 26	?	79 ± 11	.	74 ± 7	62 ± 6	77 ± 9	62 ± ?	.	.	.
/ASCA-_____	220 ± 18	.	80 ± 10	?	75 ± 6	75 ± 5	77 ± 10	63 ± 10	?	.	.
/CLUN-MEFE	191 ± 52	.	?	?	70 ± ?	?	?	?	82 ± ?	.	.
/CLUN-ARNU	196 ± 33	.	?	.	74 ± 10	?	?	64 ± ?	.	.	.
/CLUN-XETE	201 ± 36	.	63 ± 9	59 ± 4	63 ± 4	?	57 ± 5	?	?	?	?
/CLUN-CLUN	233 ± 28	?	75 ± 12	?	74 ± 9	77 ± ?	74 ± 20	63 ± ?	78 ± ?	?	.
/CLUN-_____	208 ± 21	.	69 ± 8	62 ± 7	69 ± 4	80 ± ?	67 ± 12	63 ± 6	75 ± 9	?	.
/MEFE	156 ± ?	.	?	?	.	?	?	?	?	?	?
TSHE Series	.	?	71 ± 5	62 ± 4	72 ± 3	75 ± 6	70 ± 6	64 ± 3	78 ± 5	?	?
THPL/OPHO	455 ± 84	.	.	.	.	.	?	?	?	.	.
/ATFI-ADPE	.	.	?	.	.	?	.	?		.	.
/ATFI-ATFI	.	.	?	?	.	62 ± 12	68 ± ?	65 ± 18	82 ± 7	.	.
/ATFI-_____	365 ± 116	.	71 ± ?	?	.	62 ± 12	68 ± ?	65 ± 18	82 ± 7	.	.
/ADPE	260 ± 93	.	89 ± 9	.	80 ± ?	77 ± 9	82 ± ?	?	.	.	.
/GYDR	293 ± 151	.	.	?	?	60 ± ?	?	60 ± ?	?	.	.
/ASCA-MEFE	209 ± 69	.	65 ± ?	68 ± ?	68 ± ?	?	?	?	71 ± ?	.	.
/ASCA-TABR	529 ± ?	.	?	?	?	?	?	?	?	.	.
/ASCA-ASCA	284 ± 54	?	76 ± 13	?	77 ± 12	?	?	58 ± 5	74 ± ?	.	.
/ASCA-_____	302 ± 45	.	76 ± 9	68 ± ?	74 ± 9	63 ± 9	?	58 ± 5	73 ± 11	.	.
/CLUN-MEFE	205 ± 48	.	66 ± 4	67 ± 10	69 ± 4	59 ± 15	74 ± ?	54 ± ?	74 ± 7	80 ± ?	.
/CLUN-TABR	?	.	?	?	?	?	?	?	?	.	.
/CLUN-XETE	184 ± 45	?	60 ± ?	?	62 ± ?	?	?	?	?	.	.
/CLUN-CLUN	225 ± 28	?	78 ± 8	65 ± ?	71 ± 6	60 ± 10	72 ± ?	62 ± 13	?	.	.
/CLUN-_____	216 ± ?	73 ± ?	74 ± 5	65 ± 5	71 ± 3	63 ± 7	74 ± 10	63 ± 10	.	.	.
THPL Series	.	73 ± ?	74 ± 4	67 ± 5	70 ± 3	65 ± 5	75 ± 6	63 ± 5	79 ± 4	81 ± 12	.
TSME/STAM-LUHI	235 ± ?	.	.	?	.	.	.	.	60 ± ?	47 ± ?	42 ± ?
/STAM-MEFE	128 ± ?	.	?	?	68 ± ?	.	?	.	78 ± 4	68 ± ?	53 ± ?
/STAM-_____	.	.	.	.	.	.	.	.	.	.	.
/CLUN-MEFE	198 ± 31	.	.	60 ± ?	58 ± 11	?	54 ± ?	.	65 ± 6	61 ± 6	56 ± 10
/CLUN-XETE	175 ± 37	.	?	60 ± ?	63 ± ?	?	56 ± 18	.	69 ± ?	?	?
/CLUN-_____	.	.	.	.	.	.	.	.	.	.	.
/MEFE-LUHI	?	.	?	52 ± 8	58 ± ?	.	?	.	47 ± ?	49 ± ?	42 ± 8
/MEFE-XETE	?	.	?	54 ± 10	?	.	.	.	60 ± ?	50 ± 7	44 ± ?
/MEFE-_____	—	.	.	.	.	.	.	.	.	.	.
/XETE-LUHI	240 ± ?	.	.	36 ± ?	.	.	.	.	49 ± ?	41 ± ?	33 ± 4
/XETE-VAGL	184 ± 52	?	50 ± 9	53 ± 4	60 ± 4	?	58 ± ?	.	61 ± 11	47 ± ?	48 ± 5
/XETE-VASC	174 ± 36	.	54 ± ?	43 ± 3	57 ± ?	?	51 ± ?	.	49 ± 12	46 ± 10	44 ± 6
/XETE-_____	.	.	.	?	.	.	.	.	?	?	?
TSME Series	.	?	58 ± 5	52 ± 3	58 ± 4	?	57 ± 7	.	62 ± 4	53 ± 4	43 ± 4
ABLA/CACA-LEGL	?	.	.	57 ± ?	.	.	.	.	?	?	.
/CACA-LICA	?	.	?	?	.	.	.	.	?	?	.
/CACA-VACA	?	.	?	?	.	.	.	.	?	?	.
/CACA-CACA	?	.	.	?	.	.	.	.	?	?	.
/CACA-_____	126 ± 26	.	?	57 ± 7	.	.	.	.	?	?	.
/STAM-MEFE	210 ± 34	.	.	?	.	.	.	.	69 ± 6	70 ± ?	.
/STAM-LICA	219 ± 54	.	?	64 ± ?	?	.	.	.	77 ± 7	68 ± ?	.
/STAM-_____	.	.	61 ± ?	63 ± ?	?	.	.	.	72 ± 4	69 ± 5	.
/CLUN-MEFE	171 ± 43	.	60 ± ?	?	?	.	?	.	68 ± 8	60 ± ?	.
/CLUN-XETE	183 ± 27	.	60 ± 12	56 ± ?	62 ± ?	.	?	.	70 ± 12	?	.
/CLUN-CLUN	187 ± ?	.	60 ± ?	66 ± ?	66 ± ?	55 ± ?	?	.	81 ± ?	?	.
/CLUN-_____	.	.	60 ± 8	59 ± 9	64 ± 11	56 ± ?	?	.	69 ± 6	63 ± 12	.
/MEFE-LUHI	217 ± 56	.	.	40 ± 3	.	.	.	.	38 ± ?	?	.
/MEFE-VASC	?	.	.	47 ± ?	.	.	.	.	?	?	.

(con.)

Series/habitat type-phase	Basal area	PIPO	PSME	PICO	LAOC	ABGR	PIMO	THPL	PIEN	ABLA	TSME
/MEFE-COOC	123 ± 24	.	?	57 ± ?	54 ± ?	.	?	.	61 ± ?	?	.
/MEFE-XETE	190 ± ?	.	?	55 ± 4	?	.	.	.	?	?	.
/MEFE-___	.	.	?	54 ± ?	54 ± ?	.	?	.	49 ± 9	?	.
/VACA	?	.	?	?	?	.	.	.	?	?	.
/XETE-LUHI	129 ± 31	.	.	40 ± 7	.	.	.	.	43 ± ?	33 ± ?	.
/XETE-VASC	101 ± 17	.	.	46 ± 5	?	.	.	.	56 ± ?	?	.
/XETE-COOC	166 ± 32	.	46 ± 10	53 ± 5	?	.	?	.	58 ± 10	55 ± 16	.
/XETE-VAGL	139 ± 34	.	46 ± ?	56 ± 3	?	.	.	.	?	?	.
/XETE-___	.	.	46 ± 6	48 ± 3	?	.	?	.	56 ± 7	43 ± 10	.
/LUHI	126 ± 74	.	.	24 ± ?	.	.	.	.	?	?	.
/VAGL	?	.	?	?	?	.	.	.	?	?	.
/CARU	?	.	?	?	.	.	.	.	.	?	.
ABGR Series	.	78 ±	69 ±	60 ±	67 ±	62 ±	65 ±	.	74 ±	.	.
ABGR/SETR	.	.	.	.	?	?	?	.	?	?	?
/ASCA-MEFE	232 ± ?	.	66 ± ?	67 ± ?	?	?	.	.	73 ± ?	.	.
/ASCA-TABR	192 ± 74	.	78 ± ?	.	?	67 ± ?	?	.	79 ± ?	.	.
/ASCA-ASCA	212 ± 20	?	78 ± 6	.	72 ± ?	69 ± 11	69 ± ?	.	75 ± ?	.	.
/ASCA-___	.	78 ± ?	76 ± 5	67 ± ?	72 ± ?	68 ± 9	68 ± ?	.	76 ± 8	.	.
/CLUN-MEFE	170 ± 37	.	60 ± 11	62 ± ?	68 ± ?	56 ± ?	?	.	75 ± 9	.	.
/CLUN-TABR	187 ± ?	.	?	.	?	?	?	.	?	.	.
/CLUN-XETE	200 ± 24	?	64 ± 3	63 ± 5	66 ± 3	60 ± 10	?	.	76 ± ?	.	.
/CLUN-PHMA	181 ± 19	83 ± 10	70 ± 4	?	71 ± 10	55 ± ?	?	.	.	.	.
/CLUN-CLUN	215 ± 30	84 ± ?	72 ± 9	65 ± ?	72 ± ?	63 ± 11	72 ±	.	?	.	.
/CLUN-___	.	81 ± 8	67 ± 3	63 ± 3	68 ± 2	57 ± 6	65 ± 12	.	74 ± 8	.	.
/LIBO-LIBO	122 ± ?	?	66 ± ?	56 ± ?	?	?	?	.	.	.	.
/LIBO-XETE	173 ± 20	?	?	55 ± ?	63 ± ?	60 ±	?	.	?	.	.
/LIBO-___	.	64 ± ?	62 ± 12	55 ± 4	65 ± 12	60 ± ?	?	.	?	.	.
/XETE-COOC	254 ± ?	77 ± ?	65 ± ?	55 ± ?	62 ± ?	?	.	.	?	.	.
/XETE-VAGL	161 ± 28	69 ± ?	64 ± 5	59 ± 4	65 ± 11	50 ± ?	.	.	63 ± ?	.	.
/XETE-___	.	73 ± 9	63 ± 5	58 ± 4	64 ± 5	50 ± 14	?	.	70 ± 10	.	.
/VAGL	?	.	?	?	?	.	.	.	?	?	.
/PHMA-COOC	220 ± ?	?	78 ± ?	?	?	?	.	.	.	.	.
/PHMA-PHMA	208 ± 36	86 ± 18	72 ± 6	?	?	57 ± ?	.	.	.	.	.
/PHMA-___	.	84 ± 15	73 ± 5	?	?	57 ± ?	.	.	.	.	.
/SPBE	167 ± ?	?	56 ± ?	?	.	?	.	.	.	.	.
ABLA Series	.	.	54 ± 5	51 ± 3	61 ± 6	50 ± 10	53 ± ?	.	64 ± 3	56 ± 7	.
PSME/PHMA-SMST	196 ± 32	75 ± 6	71 ± 5	?	74 ± ?	.	.	.	.	.	.
/PHMA-PHMA	167 ± 23	69 ± 6	65 ± 5	.	.	.	.	.	.	.	.
/VACA	?	?	?	60 ± ?	?	.	.	.	.	.	.
/VAGL	?	?	?	?	?	.	.	.	.	.	.
/SYAL	?	62 ± ?	64 ± ?	?	.	.	.	.	.	.	.
/SPBE	?	?	?	?	.	.	.	.	.	.	.
/CARU-ARUV	127 ± 48	71 ± 10	65 ± ?	?	?	.	.	.	.	.	.
/CARU-CARU	162 ± ?	?	?	?	?	.	.	.	.	.	.
/CARU-___	.	71 ± 8	65 ± ?	?	?	.	.	.	.	.	.
/CAGE	?	?	?	?	?	.	.	.	.	.	.
/FEID	139 ± ?	64 ± ?	65 ± ?	.	.	.	.	.	.	.	.
/AGSP	?	.	.	.	.	.	.	.	.	.	.
PSME Series	.	69 ±	67 ±	59 ±	67 ± ?	.	.	.	.	.	.
PIPO/PHMA	?	63 ± 6	.	.	.	.	.	.	.	.	.
/SYAL	145 ± ?	59 ± 5	.	.	.	.	.	.	.	.	.
/FEID	125 ± ?	?	.	.	.	.	.	.	.	.	.
/AGSP	88 ± ?	44 ± 4	.	.	.	.	.	.	.	.	.
PIPO Series	.	60 ± 3	.	.	.	.	.	.	.	.	.
PICO/VASC	?	.	.	?	.	.	.	.	.	.	.

APPENDIX G: NORTHERN IDAHO HABITAT TYPE FIELD FORM

NAME **DATE**

LANDFORM:	CANOPY COVERAGE CLASS:		Plot No.
1-Major ridge, exposed	T = Rare to <1%	4 = 50 to <75%	Location
2-Major ridge, protected	1 = 1 to <5%	5 = 75 to <95%	T., R., S.
3-Minor ridge, protected	2 = 5 to <25%	6 = 95 to 100%	Elevation
4-Plateau	3 = 25 to <50%		Aspect
5-Terrace, not flooded			Slope % % % %
6-Stream or flooded terrace			Landform
7-Valley slope	CONFIGURATION:	POSITION:	Position
8-Valley bottom	Horiz./Vert.	1-Top	Configuration H/V / / / /
9-Canyon floor	1-Convex	2-Upper 1/3	Stand structure
10-Basin, >1/4 mi. dia.	2-Flat	3-Mid 1/3	Stand Age Meas.
11-Basin, <1/4 mi. dia.	3-Concave	4-Lower 1/3	Est.
	4-Undulating	5-Bottom	Remarks:

Note: Rate trees (>4" d.b.h.) and regen. (<4" d.b.h.)
Stand structure: even-aged, 2-aged, uneven-aged

TREES Scientific name	Abbrev.	Common name	Canopy coverage class
1. *Abies grandis*	ABGR	grand fir	/ / / /
2. *Abies lasiocarpa*	ABLA2	subalpine fir	/ / / /
3. *Betula papyrifera*	BEPA	paper birch	/ / / /
4. *Larix lyallii*	LALY	alpine larch	/ / / /
5. *Larix occidentalis*	LAOC	western larch	/ / / /
6. *Picea engelmannii*	PIEN	Engelmann spruce	
7. *Pinus albicaulis*	PIAL	whitebark pine	/ / / /
8. *Pinus contorta*	PICO	lodgepole pine	/ / / /
9. *Pinus monticola*	PIMO	western white pine	/ / / /
10. *Pinus ponderosa*	PIPO	ponderosa pine	/ / / /
11. *Populus tremuloides*	POTR	quaking aspen	/ / / /
12. *Pseudotsuga menziesii*	PSME	Douglas-fir	/ / / /
13. *Thuja plicata*	THPL	western redcedar	/ / / /
14. *Tsuga heterophylla*	TSHE	western hemlock	/ / / /
15. *Tsuga mertensiana*	TSME	mountain hemlock	/ / / /
SHRUBS AND SUBSHRUBS			
1. *Acer glabrum*	ACGL	Rocky Mountain maple	
2. *Arctostaphylos uva-ursi*	ARUV	bearberry	
3. *Berberis repens*	BERE	Oregon-grape	
4. *Gaultheria humifusa*	GAHU	western wintergreen	
5. *Holodiscus discolor*	HODI	ocean-spray	
6. *Ledum glandulosum*	LEGL	Labrador-tea	
7. *Linnaea borealis*	LIBO2	twinflower	
8. *Menziesia ferruginea*	MEFE	fool's huckleberry	
9. *Oplopanax horridum*	OPHO	devil's club	
10. *Phyllodoce empetriformis*	PHEM	red mountain-heath	
11. *Physocarpus malvaceus*	PHMA	ninebark	
12. *Rhododendron albiflorum*	RHAL	white rhododendron	
13. *Ribes lacustre*	RILA	prickly currant	
14. *Rosa gymnocarpa*	ROGY	baldhip rose	
15. *Spiraea betulifolia*	SPBE	shiny-leaf spiraea	
16. *Symphoricarpos albus*	SYAL	common snowberry	
17. *Taxus brevifolia*	TABR	Pacific yew	
18. *Vaccinium caespitosum*	VACA	dwarf huckleberry	
19. *Vaccinium globulare*	VAGL	blue huckleberry	
20. *Vaccinium membranaceum*	VAME	big huckleberry	
21. *Vaccinium scoparium*	VASC	grouse whortleberry	
FERNS			
1. *Adiantum pedatum*	ADPE	maidenhair fern	
2. *Athyrium filix-femina*	ATFI	lady-fern	
3. *Gymnocarpium dryopteris*	GYDR	oak-fern	
FORBS			
1. *Aralia nudicaulis*	ARNU3	wild sarsaparilla	
2. *Asarum caudatum*	ASCA3	wild ginger	
3. *Clintonia uniflora*	CLUN	queencup beadlily	
4. *Coptis occidentalis*	COOC2	western goldthread	
5. *Cornus canadensis*	COCA	bunchberry dogwood	
6. *Disporum hookeri*	DIHO	Hooker fairybells	
7. *Dodecatheon jeffreyi*	DOJE	Jeffrey's shooting star	
8. *Galium triflorum*	GATR	sweetscented bedstraw	
9. *Goodyera oblongifolia*	GOOB	rattlesnake-plantain	
10. *Ligusticum canbyi*	LICA2	Canby's licorice-root	
11. *Mitella breweri*	MIBR	Brewer's mitrewort	
12. *Mitella pentandra*	MIPE	alpine mitrewort	
13. *Senecio triangularis*	SETR	arrowleaf groundsel	
14. *Smilacina stellata*	SMST	starry Solomon-plume	
15. *Streptopus amplexifolius*	STAM	twisted-stalk	
16. *Thalictrum occidentale*	THOC	western meadowrue	
17. *Tiarella trifoliata*	TITR	coolwort foamflower	
18. *Trautvetteria caroliniensis*	TRCA3	false bugbane	
19. *Viola glabella*	VIGL	pioneer violet	
20. *Viola orbiculata*	VIOR2	round-leaved violet	
21. *Xerophyllum tenax*	XETE	beargrass	
GRAMINOIDS			
1. *Agropyron spicatum*	AGSP	bluebunch wheatgrass	
2. *Calamagrostis canadensis*	CACA	bluejoint reedgrass	
3. *Calamagrostis rubescens*	CARU	pinegrass	
4. *Carex geyeri*	CAGE	elk sedge	
5. *Festuca idahoensis*	FEID	Idaho fescue	
6. *Luzula hitchcockii*	LUHI	smooth woodrush	
		SERIES	
		HABITAT TYPE	
		PHASE	
		ADP#	

APPENDIX H: GLOSSARY

The following terms are defined **as used in this report**. The definitions should reduce misunderstanding resulting from the various interpretations of these terms according to the specialty of the user. Primary references include Hanson (1962), Ford-Robertson (1971), and Daubenmire (1968a).

Abundant. When relating to species coverages in the h.t. key and written h.t. descriptions, any species with 25 percent or greater canopy coverage.

Accidental. A species found rarely, or at most occasionally, as scattered in a given habitat.

Amplitude, ecological. The range in environmental and community conditions (competition) within which a plant species is capable of establishing and growing (similar to term "niche breadth" of animal ecology).

Association. An abstract climax plant community type (after Daubenmire 1968a) in which all component stands are comprised of the same vegetational layers with limited variability in species composition and in habitat conditions.

Basal area. The cross-sectional area of a tree trunk measured at breast height (4.5 ft [1.4 m]) above the ground; summed for all trees on a given stand or type and expressed on a per-acre basis.

Bench, benchland. An area of flat or gently sloping terrain (<15 percent slope).

Browse. (Noun) Shrubby forage consumed especially by large animals; (Verb) To eat shrubby foliage.

Canopy coverage. The area covered when an imaginary polygon is circumscribed about a plant's foliage and projected to a horizontal plane and expressed as a percentage of the sampling unit (Daubenmire 1968a). The collective canopy coverage of all individuals of a species on a plot or stand is expressed as a percentage of the total area or as a coverage class (see key to habitat types).

Classification. The arrangement of entities according to similarities and differences in their properties.

Climax community. The culminating stage in plant (forest) succession for a given habitat, that develops and perpetuates itself in the absence of disturbance, natural or otherwise.

Climax species. A species that is self-perpetuating in the absence of disturbance, with no evidence of replacement by other species.

Climax, types of...in relation to environment (Polyclimax Concept of Tansley 1935).

- **Climatic climax**. The climax plant community that develops on normal (zonal) sites with well-drained, medium-textured soils, and flat to gently sloping topography.
- **Edaphic climax**. A deviation in climax community caused by abnormal soils (or parent materials).
- **Topographic climax**. A deviation from the climatic climax due to an unusual microclimate caused by topographic influences.
- **Topoedaphic climax**. Combinations of edaphic and topographic conditions that deflect climax from the characteristic community developing under the prevailing macroclimate. (Example: *Pseudotsuga menziesii* stands occupying thin-soiled, rocky, south-facing slopes surrounded by more mesic forest types.)

Common. When relating to plant coverage in the h.t. key and narratives, any species with 1 percent or greater canopy coverage.

Community (plant community). An assemblage of plants occurring in a defined area but denoting no particular ecological status or successional stage.

Constancy. The percentage of stands in a habitat type containing a given species. (Appendix C expresses constancy by class: 1 = 5 to 15 percent, 2 = 16 to 25, etc.)

d.b.h. (diameter at breast height). Tree trunk diameter at 4.5 ft (1.4 m) above the ground.

Depauperate. Describes a sparse undergrowth coverage; this condition is caused (in northern Idaho) by dense forest canopies and often accompanied by a deep duff layer.

Disjunct. A small (usually) portion of a population that is geographically separated from the main population.

Ecosystem. Any community of organisms and its environment that forms an interacting system; size and boundaries of the system are arbitrarily stipulated.

Ecotone. The boundary or transition zone between adjacent plant communities; it often separates different habitat types.

Ecotype. A portion of a species population that is adapted to a particular habitat and not necessarily phenotypically distinguishable from the remainder of the population.

Edaphic. Referring to soil.

Endemic. Confined to a particular geographic area.

Forb. An herbaceous plant that is not a graminoid.

Frequency. The percentage of subsampling units in a single sample stand that contains a given species; though generally a measure of the uniformity of distribution of a species in a stand, its value is dependent on the size and shape of the subsample plots.

Graminoid. All grasses (Gramineae) and grasslike plants, including sedges (*Carex* spp.) and rushes (*Juncus* and *Luzula* spp.).

Habitat type. All land areas potentially capable of producing similar plant communities (associations) at climax.

Grove, groveland. Referring to physiognomy (gross appearance) of vegetation that is similar to savanna except that plants of the tallest stratum (trees) occur as small clusters (groves); groves encompassed within a vegetation matrix of lower stature lifeforms constitute a groveland.

Indicator plant. A plant whose presence or coverage is indicative of certain environmental conditions. H.t. classifications employ plants with relatively narrow ecological amplitudes to denote the presence of a given series, habitat type, or phase.

Park, parkland. Referring to physiognomy (gross appearance) of vegetation; the reciprocal of grove or groveland; a patch of low vegetation (park) or patches of low vegetation distributed over a rather continuous forest (parkland).

Phase. A subdivision of habitat type representing minor differences in climax or mature vegetation that may reflect environmental differences or floristic and/or historic peculiarities within the h.t. (see Crawford and Johnson 1984).

Phenotype. The physical appearance or measurable attributes of an individual or a group distinguished by possession of similar attributes—in contrast to "genotype," which is a measure of genetic constitution or similarities.

Physiography. The study and description of landforms, particularly their genesis.

Poorly represented. When relating to plant coverage in the h.t. key or written descriptions, any species with less than 5 percent canopy coverage.

Riparian. Vegetation bordering water courses, lakes, swamps, or marshes.

Scarce. When referring to plant coverage in the h.t. key or written descriptions, any species that is absent or has less than 1 percent coverage.

Scree slope. Any slope covered with loose rock fragments, including the accumulation of rock at a cliff or slope base (talus) as well as loose, unstable material lying on slopes without cliffs.

Seral. A species or community that is replaced (at least in part) by another species or community as succession occurs.

Series. A group of habitat types having the same potential climax tree species.

Site index. An indicator of forest productivity as referenced by the height attained by a given tree species at a designated base age (usually 50 or 100 years, total or breast height age).

Stand. A plant community that is relatively uniform in composition (undergrowth and canopy species), structure (diameter or age distribution), and habitat conditions (does not correspond to Northern Region, Timber Management Division concept of stand; see instructions to users of key section).

Stockability factor. An estimate of the stocking potential on a given site; for example, a factor of 0.8 indicates the site is capable of supporting only 80 percent of normal stocking as indicated in yield tables or basal area on site index regressions.

Stocking. A general term for the number of trees or basal area per acre relative to some desirable number or basal area for best growth and management.

Succession. A term for changes in the biota (plant communities) of a given area relative to some previous state, usually changes toward some hypothetical dynamic equilibrium point, climax.

Terrace, stream. A relatively flat, horizontal or gently inclined surface, of depositional or erosional origin, bounded by steeper ascending and descending slopes on either side.

Undergrowth. Collectively, those plants shrub-sized and less growing under a forest canopy.

Understory. In a forest stand that portion of the trees below the overstory, including seedlings, saplings, and suppressed trees.

Union. A vegetation layer consisting of one or more species having similar environmental amplitudes within a limited geographic area; presence of union is indicative of particular environmental conditions.

Well represented. When relating to plant coverages in the h.t. key or descriptions, any species having a 5 percent or greater coverage.

Yield capability. The mean annual increment attainable in a fully stocked natural stand at the age of culmination of mean annual increment, expressed in volume per acre per year. (See a forest mensuration text for the distinction between "mean annual increment" and growth in a specific year, or period of years, termed "periodic annual increment.")

☆ U.S. GOVERNMENT PRINTING OFFICE:1987- 573-039/61042

Cooper, Stephen V.; Neiman, Kenneth E.; Steele, Robert; Roberts, David W. 1987. Forest habitat types of northern Idaho: a second approximation. Gen. Tech. Rep. INT-236. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 135 p.

The addition of more than 900 plots to the Daubenmire's original 181-plot database has resulted in a refinement of their potential natural vegetation-based land classification for northern Idaho. A diagnostic, indicator species-based key is provided for field identification of the eight climax series, 40 habitat types, and 47 phases. Recognized syntaxa are described by occurrence, environment, vegetation, and management implications.

KEYWORDS: northern Idaho, habitat types, forest communities, plant associations, hierarchical classification

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

The Intermountain Research Station territory includes Montana, Idaho, Utah, Nevada, and western Wyoming. Eighty-five percent of the lands in the Station area, about 231 million acres, are classified as forest or rangeland. They include grasslands, deserts, shrublands, alpine areas, and forests. They provide fiber for forest industries, minerals and fossil fuels for energy and industrial development, water for domestic and industrial consumption, forage for livestock and wildlife, and recreation opportunities for millions of visitors.

Several Station units conduct research in additional western States, or have missions that are national or international in scope.

Station laboratories are located in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

UNITED STATES CONSTITUTION
We the People
1787 ★ BICENTENNIAL ★ 1987

DATE DUE

APR 30 1992	
Ret'd MAR 31 1992	
~~DEC 23 1996~~	